Ergonomic Exposure to Company XYZ's

Employees by Adjusting to a Mixed

Engine Model Assembly Line

by

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ABSTRACT

The purpose of the study was to evaluate, using different ergonomic tools, the major areas of the body that are potentially being exposed to ergonomic risk factors. In addition, the scope of this research paper focuses on different ways to improve the current process (from a worker's standpoint) and make recommendations if applicable. In order to achieve the purpose various goals were developed to identify the presence of common risk factors (repletion, force, and duration) that could potentially lead to the development of cumulative trauma disorders.

Through a literature review, task analysis, and the use of three ergonomic surveys, these goals were achieved. The literature review consisted of topics such as ergonomic analysis, an overview of different cumulative trauma disorders, and workplace design issues. Three ergonomic surveys were used to identify the extent of the risk factors employees may be exposed to. The three surveys that were used to analyze the

ergonomic risk factors were Rapid Upper Body Assessment (RULA), Rapid Entire Body Assessment (REBA), and the Baseline Risk Identification of Ergonomic Factors (BRIEF) survey.

It appears, through accomplishing the goals set at the beginning of the study, that the processes the workers are performing at Company XYZ are exposing them to potentially developing cumulative trauma disorders. As a result, recommendations are included in the study as to what Company XYZ could potentially implement in order to reduce the exposure of their worker to ergonomic risk factors.

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Chapter I: Introduction

Introduction

Ergonomics, or human factors engineering, is defined by Chengalur, Rodgers, and Bernard in Kodak's Ergonomic Design for People at Work, as "a multidisciplinary activity striving to assemble information on people's capacities and capabilities and to use that information in designing jobs, products, workplaces, and equipment" (Chengalur, Rodgers, Bernard, 2004, p. 2). In other words, ergonomics is the science of designing equipment and the workplace to fit the employee conducting the work. Having a well designed workplace and equipment leads to many benefits for a company. These benefits include improved productivity, health, and safety, thus leading to a reduction in accidents and injuries (Chengalur, Rodgers, Bernard, 2004). With improved productivity, health, and safety through ergonomics this will lead to greater profits and less payouts in work related accidents and injuries. If employees are feeling safer and healthier, they will be more inclined to buy into the management system and will be more apt to buy into future systems.

Ergonomics is an important program for any company to utilize and implement in everyday operations. This is especially true in a manufacturing facility, in which employees are subject to making the same repetitive movements over the course of an extended duration. This could potentially lead to the development of a cumulative trauma disorder (CTD). In fact, the average employee loses two days per year because of a musculoskeletal disorder (Putz-Anderson, 1988). According to Vern Putz-Anderson (1988), cumulative trauma disorders (CTDs) is defined as the adverse health effects that arise from chronic exposure to unnatural motions and postures (Putz-Anderson, 1988).

A cumulative trauma disorder is a general term used to describe many different types of musculoskeletal disorders caused my repetitive motions, extended duration, and awkward posture. These disorders consist of; carpal tunnel syndrome (CTS), radial/cubital tunnel syndrome, lateral/medial epicindylitis, tailor's bunion, march fracture, low back pain, thoracic outlet syndrome, tenosynovitis, bursitis, Raynaud's syndrome, rotator cuff tendinitis, pronator teres syndrome, tension neck syndrome, ganglionic cyst, DeQuervain's disease, and trigger finger (Cameron, 1996).

"More than half of the nation's workers now have jobs with the potential for CTDs. CTDs are being recognized as the leading cause of significant human suffering, loss of productivity, and economic burden, no where is more evident than the workplace" (Putz-Anderson, 1988, p. 6).

Company XYZ currently manufactures a few different engine models, ranging in size and weight. Each model (until now) is assembled on a separate assembly line. Company XYZ has developed a new (larger and heavier) engine model, which will be produced on the same fixed line as the smaller previous model. This creates an ergonomic problem when needing to adjust from working on a smaller engine to a larger engine at various times throughout a work shift.

The current process of using a fixed assembly line for mixed engine models is of ergonomic concern and has the potential of placing Company XYZ's employees at risk of developing cumulative trauma disorders.

Purpose of the Study

The purpose of the study was to evaluate, using different ergonomic tools, the major areas of the body that were potentially being exposed to ergonomic risk factors. In addition, the scope of this research paper focuses on different ways to improve the current process (from a worker's standpoint) and make recommendations if applicable. This paper helps to determine how to reduce or eliminate the potential risk factors to employees of Company XYZ as it relates to ergonomics on an engine assembly line. Reducing the potential ergonomic risk factors should lead to a decreased likelihood of an employee developing a cumulative trauma disorder (CTD).

Goals of the Study

1. Conduct a task analysis of three blocks on the existing assembly line and identify three cells (stations) to be further analyzed using various ergonomic tools
2. Measure, using different ergonomic testing tools, the extent of the exposure as well as the location of the body most exposed at these cells
3. Identify ergonomic exposures that could potentially lead to cumulative trama disorders (CTD)

Background and Significance

Company XYZ is a manufacturing facility with multiple engine assembly lines. Recently Company XYZ has started the manufacturing of a new engine model that is approximately one-third larger than the previous model. Both models are being produced and assembled on the same fixed assembly line and therefore workers must make adjustments multiple times throughout a shift to accommodate for the different sized engines. There is a potential for accidents and injuries due to this process and a potential for employees to develop cumulative trauma disorders.

Limitations of the Study

The limitations of this research are:

- The specific number of large and small engines varies from day to day. There is no way of telling how many large engines will be produced in any certain day, as well as the number of smaller engines
- This research project will focus on only three different stations on the assembly line and therefore will not evaluate the entire engine assembly line, in which there are many stations

Assumptions of the Study

- During the course of days that the author observed and completed the surveys, it is assumed that the same workers work the same stations during every workdays
- The two engines being manufactured on the assembly line were the same engines that are assembled on a daily basis

Definition of terms

BRIEF survey. Baseline Risk Identification of Ergonomic Factors survey

Cumulative Trauma Disorder (CTD). The musculoskeletal symptoms caused by repetitive excessive motions of a body part for an extended period of time (Cameron, 1996). Also known as Repetitive Trauma Disorder (RTD), Repetitive Strain Injuries (RSI), and Repetitive Motion Disorders (RMD)

Duration. The length of exposure to a risk factor (Ergo Web, 2007)

REBA survey. Rapid Entire Body Assessment survey

Repetition. The number of a similar exertion performed during a task (Ergo Web, 2007)

Risk Factor. Actions in the workplace, workplace conditions, or a combination thereof, that may cause or aggravate a Work Related Musculoskeletal Disorder (Ergo Web, 2007)

RULA survey. Rapid Upper Limb Assessment survey

Chapter II: Literature Review

Introduction

The purpose of the study was to evaluate, using different ergonomic tools, the major areas of the body that are potentially being exposed to ergonomic risk factors at Company XYZ. This section will help to introduce the concepts of assembly work and how it relates to ergonomics in Company XYZ's mixed engine line process. In order to focus on this an evaluation of various blocks on the assembly line was conducted to reveal the most ergonomically hazardous blocks. Reducing the potential ergonomic risk factors should lead to a decreased likelihood of an employee developing a cumulative trauma disorder (CTD).

Background

According to the International Ergonomics Association Executive Council,

> "Ergonomics (or human factors) is the scientific discipline concerned with the understanding of the interactions among human and other elements of a system, and the profession that applies theory, principles, data and methods to design in order to optimize human well-being and overall system performance." (International Ergonomics Association Executive Council, August 2000)

There are three major ergonomics risk factors that contribute to the development of musculoskeletal disorders, these factors are awkward posture, extreme force, and repetition.

Specific jobs and tasks may require a worker to assume a posture that is biomechanically awkward and puts stress on certain joints and surrounding soft tissue (Putz-Anderson, 1988). Awkward posture, according to Vern Putz-Anderson, is "any fixed or constrained body position, overloading the muscles and tendons, loading joints in an uneven or asymmetrical manner, or involving a static load on the musculature" (Putz-Anderson, 1988, p. 23).

Extreme force is the term used when describing the amount of force needed to perform various tasks. This is also a critical factor that contributes to the onset of CTDs (Putz-Anderson, 1988). As muscle effort increases when performing an occupational task, circulation to the muscle decreases causing more muscle fatigue (Putz-Anderson, 1988).

Jobs that require work to be done very rapidly and repetitively, such as the work at Company XYZ, involves the ergonomic risk factor know as repetition. The value that represents what repetition is can change depending on what part of the body is being measured and monitored. The more rapid and frequent the muscle contractions the greater the stress and hazard to the specific joint, muscle, or tendon (Putz-Anderson, 1988). In the case of repetition, cumulative trauma disorders can develop even if the force is small or minimal (Putz-Anderson, 1988).

Ergonomic Analysis

According to Karwowski and Marras (1999), studies in ergonomics typically consist of observing employees at work and assessing the way at which they conduct their job in the work environment (Karwowski, Marras, 1999). Job analysis is a useful tool for identifying sources for potential cumulative trauma disorders before they are developed (Putz-Anderson, 1988). A task analysis is a term that refers to the formal approach of analyzing humans at work to pin-point the specific ergonomic risk factors they are being exposed to, and to assist in the process of redesigning the workplace to further benefit the worker (Karwowski, Marras, 1999). According to Drury, a task analysis compares the demands of the specific task with the demands a worker would need to exert in order to perform the task (Drury, 1983).

Any job consists of a number of tasks. A task can be defined as any process or application which has any number of objectives or goals, one which there is a specific input and results in a specific output (Karwowski, Marras, 1999). Each task is defined as a set number of steps or elements (Putz-Anderson, 1988). Each element is a function or movement, and these elements can be determined through observing the worker perform the job (Putz-Anderson, 1988).

Conducting a task analysis is a standard step in the process of redesigning of a work environment to improve the human factors of employees. A task analysis can be used to analyze an entire system or it can be used for a portion of the existing system. According to Karwowski and Marras (1999), task analysis can be used for various applications. These applications include:

- "System function allocation
- Organizational issues
- Task design
- Human-machine interface
- Human support requirements
- System reliability analysis" (Karwowski and Marras, 1999, p. 302)

In order to conduct a task analysis there are specific steps Karwowski and Marras describe are to be followed in order. The steps in conducting a task analysis are:

1. "List the overall objectives of the task analysis
2. Identify the personnel involved with the tasks to be studied
3. Develop a detailed plan and schedule, identifying interactions with other personnel
4. Obtain support for your study at all levels
5. Identify the activities to be conducted by various members of the investigating team
6. Develop a plan to accomplish these activities" (Karwowski and Marras, 1999, p. 304)

In a study conducted by Wilson, Welbank, and Ussher entitled "Including customer requirements in the design and development of telecommunications services: the case of video telephony for people with special needs", the authors used a task analysis to define and document the requirements of service tasks. The task analysis was used to determine the sub-tasks involved for the overall service tasks (Wilson, Welbank, Ussher, 1990). The results of the study found that the analysis was used as a helpful tool in understanding the requirements of the user.

According to the literature, in order to achieve the first goal in the study a task analysis of the different assembly line positions must be conducted and identified calls or stations assessed with the proper ergonomic tools.

Overview of Ergonomic Tools

The three tools that were used in this study were the Rapid Upper Limb Assessment (RULA), Rapid Entire Body Assessment (REBA), and the Baseline Risk

Identification of Ergonomic Factors (BRIEF).

The Rapid Upper Limb Assessment Tool, or RULA, was developed by Dr. Lynn McAtamney and Dr. Nigel Corlett of the University of Nottingham's Institute of Occupational Ergonomics (Lueder, 1996). RULA is a survey method developed for use in ergonomic investigations of workplaces where work related upper limb disorders are reported or have the potential of being reported (McAtamney, 1993). This ergonomic technique evaluates individuals' exposures to postures, forces, and muscle activities that have been shown to contribute to Repetitive Strain Injuries (RSIs) or cumulative trauma disorders (Lueder, 1996). RULA is a screening tool that assesses biomechanical and postural loading on the body with particular attention to the neck, trunk, and upper limbs. A RULA assessment requires little time to complete and the scoring generates an action list, which indicates the level of intervention required to reduce the risks of injury due to physical loading on the operator or worker (McAtamney, 2002). The action list that is generated is simply an identification of which body part are exposed to ergonomic risk factors and to what extent, according to the number system set up by the survey.

In order to perform a RULA survey, an assessment of the worker's movements in the arm and wrist, lower arm, wrist posture, neck position, and trunk position must be performed by observation (Karwowski, Marras, 1999). Karwowski and Marras in 1999 stated, that in previous studies many times the changes an organization implemented to address the ergonomic issues brought to attention by the RULA survey were implemented right away and for little cost. They also go on to state that it is very important to reevaluate the same task using the same ergonomic tools once the change has taken place in order to find out if there was any improvement in the scores (Karwowski, Marras, 1999).

In a study titled "The Relation Between Work-Related Musculoskeletal Symptoms and Rapid Upper Limb Assessment (RULA) among Vehicle Assembly Workers", written by Kim, Choi, and Kim, the authors write that the RULA survey can be a useful assessment tool for evaluating ergonomic risk factors which lead to the development of cumulative trauma disorders (Kim, Choi, Kim, 1999). The RULA survey is also useful as a screening assessment tool for a more in depth analysis of the specific task, and can be used in corporation with other ergonomic assessment tools for a wider analysis (Kim, Choi, Kim, 1999). According to the conclusion of the study the RULA survey is a valid and relevant survey tool in order to identify parts of the body that are potentially being exposed to ergonomic risk factors while completing an identified task.

Rapid Entire Body Assessment (REBA) was developed to assess working postures that involve use of the whole body, statically, dynamically, rapidly changing or in an unstable manner, and where manual handling may occur (Coyle, 2005). REBA was primarily designed to provide a quick and easy gauge to determine the level of musculoskeletal risk present in the tasks being assessed. According to McAtamney, use of REBA is beneficial in supporting manual handling risk assessments where a case is needed to fund equipment or changes in working practices. Existing studies in this regard reportedly indicate good reliability and validity of REBA (Coyle, 2005). Some practice and training is recommended before using this tool, however no previous ergonomic skills are required.

REBA scores a specific posture within a task by assessing position of the trunk, neck, legs, upper arms, lower arms and wrists, and the taking into account the load or force required, hand-object coupling used, and including an activity score. A specific process, according to the survey, is used and takes into account all these factors and a REBA score is generated. The REBA score that is generated this way is then translated into a REBA action level, (between 0 and 4) which defines whether action is required to lower the score, and also the urgency of the specific job.

According to a study "Comparison of the Rapid Entire Body Assessment and the New Zealand Manual Handling 'Hazard Control Record', for assessment of manual handling hazards in the supermarket industry" written by Alison Coyle in 2005, the REBA survey can be filled out two different methods for a single task. One method is to complete the survey using the "worst posture" scenario. This would include if the employee performed a task even once but was worse than the normal posture or behavior. This takes into consideration that the employee may perform the job this way if they were not watched. The other method is the "most frequently used" posture. "These are often quite different, with the 'worst' posture only briefly held intermittently, whereas the 'most frequently used' posture may not be considered unsafe" (Coyle, 2005, p. 112). This is one reason why one person completing the REBA survey might result in a different REBA assessment score. Coyle concludes that the REBA survey is a useful ergonomic tool if the changes that are going to be implemented to help decrease the risks of work related injuries (Coyle, 2005), which in this case the results will be. This is rather easy to monitor because one only needs to compare the REBA survey scores from before and after implementing changes to determine whether the risk has been lowered or not, thus decreasing the ergonomic risk factors.

The BRIEF Survey is a quantifiable method of measuring the amount of ergonomic risk in a job (Humantech, 2007). The BRIEF Survey is designed to analyze a job with specific tasks that are repeated, and include the risk factors that are most common in the workplace. The BRIEF Survey is meant to be used in a setting where workers participate in routine jobs or tasks involving repetitive motion procedures (Humantech, 2007). The BRIEF Survey can help to identify jobs that are potentially placing employees in harm of developing CTDs, and imply the existing risk factors for various body parts (Hsu, Li, Tsai, 2003). A higher number or ranking on the BRIEF Survey indicates a more at risk location of the body when performing the specific task being analyzed.

When using the BREIF survey, Humantech suggests that one should always start by identifying the different postures and forces exerted when performing the task being analyzed (Humantech, 2007). "The BRIEF is a posture- and force-based risk assessment" (Humantech, 2007, p. 95). However, this is not to say posture and force are the only two risk factors the BRIEF Survey takes into account, duration and frequency are also added to this survey as potential risk factors.

In an article written by Hsu, Li, and Tsai in 2003, the authors wrote about the use of the BRIEF survey and how it compared to employee interviews in different high-tech industries to assess ergonomic risk factors. The results of the study explains that the BRIEF survey scores showed higher risk of certain areas of the body, in particular the left elbow and left shoulder, than explained by employee interviews (Hsu, Li, Tsai, 2003). This article found, through using the BRIEF survey, sometimes the body part where workers feel sore and pain could differ from where the BRIEF survey has identified as a risk (Hsu, Li, Tsai, 2003). This study also states the results of the BRIEF survey scores indicated the highest risks for high-tech industries have to do with unnatural postures (Hsu, Li, Tsai, 2003). The authors conclude that even though the employees did not experience discomfort where the BRIEF survey indicated pain might just not be triggered in those areas yet (Hsu, Li, Tsai, 2003). They also conclude that the BRIEF survey is consistent with the other statistical data collected using other testing methods.

Determining Ergonomic Exposures and Potential Injuries

Cumulative trauma disorders of the upper extremities have become an increasingly important proportion of workers' compensation claims over the last two decades. Cumulative indicates an injury that has developed over an extended period of time and not just a one time exposure. Trauma means bodily injury from mechanical stressors, and the word disorder refers to an ailment or abnormal condition (Putz-Anderson, 1988).

According to Vern Putz-Anderson, "cumulative trauma disorders refer to a category of physical signs and symptoms due to chronic musculoskeletal injuries where the antecedents, or causes, appear to be related to some aspect of repetitive work" (Putz-Anderson, 1988, p. 3).

One of the main reasons, proposed by Vern Putz-Anderson, that cumulative trauma disorders are increasing in numbers is because of the pace of the modern work (Putz-Anderson, 1988). Due to high demands of volume and time constraints, most occupational workers need to perform a task a large number of times (repetition) over a given amount of time (duration). Most of these jobs are simple tasks but because of the repetition, the movements a worker makes, in the hands and wrists in particular, increase the chances of developing a CTD. "More than half of the nation's workers now have jobs with the potential for CTDs. Major categories include construction, services, manufacturing, and clerical." (Putz-Anderson, 1988, p. 6). There are three basic types of injuries that result from the ergonomic risk factors found at Company XYZ; these injuries are tendon disorders, nerve disorders, and neurovascular disorders (Putz-Anderson, 1988).

Tendon disorders occur when tendons rub, either at or near the joint, against a muscle or bone resulting most often times in a dull aching sensation felt over the tendon (Putz-Anderson, 1988). Symptoms also include tenderness to the touch and discomfort in performing specific tasks. Minor tendon disorders are common and recovery is usually slow, but the condition many become more serious if the cause of the discomfort is not treated or eliminated (Putz-Anderson, 1988). Some common upper extremity tendon disorders include; tendinitis, ganglionic cyst, golfer's elbow, and rotator cuff tendonitis.

Tendinitis is a condition in which tendon inflammation occurs from a tendon which is repeatedly tensed. Tendinitis is most often caused by repetitive, minor impact on a specific area, or from a sudden more serious injury (WebMD, 2008). With repeated use of a tendon that has become swollen, tearing or fraying of the tendon fibers can occur, resulting in weakening of the tendon, which could result in permanent damage (Putz-Anderson, 1988). Incorrect posture at work or home or poor stretching or conditioning before exercise or playing sports also increases a person's risk (WebMD, 2008). Anyone can develop Tendinitis, but it is more common in adults because as tendons age they tolerate less stress, are less elastic, and are easier to tear (WebMD, 2008).

Ganglionic cyst is another tendon disorder in which the tendon sheath swells up with synovial fluid, which causes a bump under the skin (Putz-Anderson, 1988). Ganglionic cysts most commonly occur on the back of the hand, at the wrist joint and can develop on the palm side of the wrist. The cause of this disorder is repetitive flexion and extension of the wrist joint.

According to Vern Putz-Anderson golfer's elbow, or medial epicondylitis, is "an irritation of the tendon attachments of the finger flexor muscles on the inside of the elbow" (Putz-Anderson, 1988, p. 17). Golfer's elbow is a painful tendon disorder in which inflammation occurs on the ulnar side of the elbow, where the tendons of the forearm muscles attach to the bone on the inside of the elbow (Humantech, 2007). Golfer's elbow is similar to tennis elbow, but it occurs on the ulnar side of the elbow, as tennis elbow occurs on the radial side of the elbow (WebMD, 2008). Anyone who clenches their finger repetitively with a given amount of force has the potential of developing either of these disorders, not just golf and tennis players.

Nerve disorders occur from pressure on the nerve, such as pinching, rubbing, repetitive motions, or even from swelling potentially from a tendon or ligament cumulative trauma disorder (Karwowski, Marras, 1999).

"Work involving increased wrist deviation from a neutral posture in either the extension, flexion or ulnar, radial direction has been associated with carpal tunnel syndrome and other hand and wrist problems" (Karwowski, Marras, 1999, p. 769). The carpal tunnel receives its name from eight bones, called carpals, which form a tunnel-like structure in the wrist. Symptoms may include pain, numbness, or tingling in hands and wrists, especially in the thumb, index and middle fingers (Putz-Anderson, 1988).

Carpal tunnel syndrome is due to work-related procedures most often times occurring between the ages of 20 and 40, with women being five times more likely to acquire carpal tunnel syndrome than men (Masten, 1997). CTS is a mechanical malfunction of the hand and wrist, stemming from repetitive movement that shortens the size of the thenar muscles in the hand and wrist (Bigelow, 1997). Meaning carpal tunnel syndrome is caused by repetitive flexion, extension, ulnar deviation, and radial deviation of the wrist, commonly induced from work-related processes. This shortening of the thenar muscles causes CTS because it puts adverse stress on the median nerve.

During strong flexion the ligament tends to compact and/or swell. Since tendons are the strongest tissue in the body, the stress from this movement is placed directly on the median nerve. All nerves in the body have a direct line to the brain, and as a result pain is felt, which is one of the symptoms of carpal tunnel syndrome. Compacting of the nerve in the carpal tunnel is what actually results in the diagnosis of carpal tunnel syndrome (Bigelow, 1997).

Neurovascular disorders are disorders that involve both the blood vessels and the nerves (Putz-Anderson, 1988). The most common neurovascular disorder (Putz-Anderson, 1988) and potentially the most likely to develop at Company XYZ is the thoracic outlet syndrome. Thoracic outlet syndrome occurs when the nerves and blood vessels in the neck and shoulder region are pinched or compressed (Putz-Anderson, 1988). The symptoms of this disorder are similar to that of carpal tunnel syndrome in that there could be numbness or tingling in the arms and fingers, and a weak pulse in the wrist could be observed (Putz-Anderson, 1988). There is a potential for this disorder to occur at Company XYZ because two of the three stations identified and analyzed with the three ergonomic tools consist of the worker repetitively extending their arms above shoulder height in order to engage a specific tool on the assembly line.

Workplace Design

The assembly line is often described as a process that uses machines to move material from one place to another, but in practice, machines are not always needed. For instance, Company XYZ assembles their engines manually with many different steps and many different workers, and at most stations without the benefit of machinery. At its most basic, an assembly line is a series of stations at which people or machines add to or assemble parts for a product. One of the values of the assembly line is its versatility: it can be simple, but it has the capacity to be very complex and productive.

In designing a workplace ergonomically, the key is to make the job fit the worker, and not make the worker fit the job (Putz-Anderson, 1988). However, a company cannot simply design a workplace for a specific type of person, such as the assembly line at Company XYZ in which the lines are designed for the average 5'9"-5'11" male worker. This is not ergonomically efficient especially when the average worker at Company XYZ on the stations identified is a 5'5" female employee. This workplace should be designed so that most people who perform the tasks can do so in a safe manner while still performing effectively (Chengalur, Rodgers, Bernard, 2004).

According to Karwowski and Marras in 1999, there are certain steps in designing clothing, tools, workstations, and equipment for the body (Karwowski and Marras, 1999). These steps include:

1. "Select those anthropometric measures that directly relate to defined design dimensions
2. For each of these pairings, determine whether the design must fit only one

given percentile of the body dimension, or a range along that body dimension

3. Combine all selected design values in a careful drawing, mock-up, or computer model to ascertain that they are compatible
4. Determine whether one design will fit all users" (Karwowski and Marras, 2003, p. 142)

One factor to consider in designing a work space is the physical dimensions of the workers (Putz-Anderson, 1988). A goal, when designing or redesigning a work station, is to minimize the reach limits to allow for easier accessibility to the needed components to perform the task, and also to minimize excessive reaching (Putz-Anderson, 1988). This would help to minimize or eliminate specific ergonomic risk factors of a task that could potentially lead to the development of cumulative trauma disorders. Current as well as new work stations should be evaluated for adequate anthropometrics (Putz-Anderson, 1988). Anthropometrics is the science of measuring human bodies and body parts (Karwowski and Marras, 1999). This goes along with the concept of designing the workplace to the human and not the other way around. Anthropometric tables have been created that offer listings of size measurements of adult populations, male and female that are sometimes used when designing the workplace (Putz-Anderson, 1988).

According to Vern Putz-Anderson, the height of the workplace has a major impact on developing cumulative trauma disorders and is very important when considering workplace design (Putz-Anderson, 1988). In the case of Company XYZ the assembly line is fixed and cannot move higher or lower to accommodate people of different heights. This causes a problem because if the work area is too low then workers are going to have to bend over to reach the area they are trying to assemble the engines. This can lead to neck, lower back, and shoulder discomfort and soreness, and can lead to the development of cumulative trauma disorders (Putz-Anderson, 1988). On the other hand, if the line is too high for the workers, which seems to be a major concern at Company XYZ, there is a need to hold the arms further away from the body and a need to lift the shoulders to reach the area. Based on a quote by Vern Putz-Anderson, "Elbow height is determined with the elbow held close to the body and bent at 90 degrees" (Putz-Anderson, 1988, p. 64), this assembly line does seem to accommodate the average male who is between 5'9" and 5'11". This is because the elbow height for the average male worker is approximately the same as the tool height when the elbow is at a 90-degree angle and held close to the body. (Putz-Anderson, 1988).

At Company XYZ, the workers that were analyzed using the three ergonomic tools were assembling the engines while standing. Vern Putz-Anderson states that as long as someone is standing a certain amount of static force is required by the muscles and joints of the feet, knees, and hips (Putz-Anderson, 1988). This increased muscle fatigue and stress and therefore increases the potential for development on a cumulative trauma disorder.

When a worker is performing a task that involves standing, the distance in front of that worker and the height from the ground at which the task is being performed can be determined by the simple Snook Table. The Snook Table is a table that presents various measurements as to what the optimum distances a worker, male or female, should perform a task at. The distances are measurements that will accommodate for a certain percentile of the male of female adult population. The average distance in front of a male worker with their elbows at a 90-degree angle, which is optimum, is between 7.8 and 17.5 inches, and the height from the ground to the workstation should be 45.3 inches. These measurements are based on the top 97.5th percentile of males. The distances females should be working at are going to be less than that of males. To accommodate the 97.5th percentile of females the distance in front with elbows at a 90-degree angle is between 7 and 16 inches, and the distance from the ground (the potential height of the assembly line) is 35.2 inches. Currently the assembly line at Company XYZ is 35 inches high, but that distance is increased because of the engine height being 17 inches on top of the line, and therefore the work that is being done assembling the engine is done at a height of 52 inches. This height is too high and does not accommodate ergonomically, according to the Snook Table, either males or females when the elbows are bent at 90 degrees.

According to Vern Putz-Anderson, there are three major guidelines or principles to consider when designing the workplace to reduce ergonomic risk factors. The three principles are:

1. "Reduction of extreme joint movement
2. Reduction of excessive force levels
3. Reduction of highly repetitive and stereotyped movements" (Putz-Anderson, 1988, p. 87)

These three principles could potentially be useful for Company XYZ to consider if they choose to potentially implement changes to the assembly line presented in the recommendations section of this paper.

Summary

A review of the literature suggests that workers on the assembly line at Company XYZ have the potential of developing cumulative trauma disorders. Considering that Company XYZ has an assembly line that is potentially exposing workers to the three key factors in developing cumulative trauma disorders (excessive force, repetitive motion, and awkward posture), the literature suggests there is a potential for workers to develop cumulative trauma disorders. It is imperative that an assessment be conducted, using the various proposed ergonomic tools in order to assess the extent of ergonomic exposure workers are being subject to. In order to reduce the potential exposure conclusions and recommendations must be drawn from the assessments.

Chapter III: Methodology

Introduction

The purpose of the study is to evaluate, through observations and the use of different ergonomic tools, the major areas of the body that are potentially being exposed to ergonomic risk factors. In addition, the scope of this research paper will focus on different ways to improve the current process (from a worker's standpoint) and make recommendations if applicable. The main goals that were identified to be accomplished or proven throughout the study are as follows:

1. Conduct a task analysis of three blocks on the existing assembly line and identify three cells (stations) to be further analyzed using various ergonomic tools
2. Measure, using different ergonomic testing tools, the extent of the exposure as well as the location of the body most exposed at these cells
3. Identify ergonomic exposures that could potentially lead to cumulative trauma disorders (CTD)

This chapter will provide an explaination of the methods used in this study. Included in this chapter is subject selection and description, instrumentation, data collection procedures, data analysis, and limitations of the study.

Process Selection and Description

A task analysis was conducted by observing the work tasks, physical demands (including measured distances), and behaviors of the workers to determine potential risk factors of each of the cells in the red, blue, and yellow block of the assembly line. The data collected was then input into tables and used to determine which cells potentially expose the workers to the ergonomic risk factors most in need of change. This data was also used to identify potential opportunities for controls. The cells that were identified using this task analysis as having the highest potential of contributing to the development of a cumulative truama disorder (by the Safety Director and the author) were then analyzed further using three different ergonomic assessment tools. The three ergonomic tools used are the Rapid Upper Limb Assesment (RULA) survey, Rapid Entire Body Assesment (REBA) survey, and the Humantech BRIEF survey. Two positions on the assembly line were identified through the use of the task analysis and one was identified as a potential concern by the Safety Director at Company XYZ.

Instrumentation

The use of the Rapid Upper Limb Assesment (RULA), Rapid Entire Body Assesment (REBA), and the Humantech BRIEF survey were used to identify and evaluate the potential Ergonomic concerns of exposed workers. These surveys were used in conjuction to determine the position of the body most exposed as well as the extent of the exposure. The BRIEF survey is a survey created by Humantech and was used for educational purposes only.

The Rapid Upper Limb Assessment identifies and evaluates repetition, force, and awkward posture as risk factors contributing to the development of cumulative trauma disorders in assembly line workers. The parts of the body that are assessed by the RULA survey include the wrists, forearms, elbows, shoulders, neck, and the trunk. The Rapid Entire Body Assessment focusses on the same risk factors as the RULA survey (repetition, force, and awkward) and assesses most of the same body parts. The RULA survey addresses the wrists, forearms, elbows, neck, trunk, back, legs, and knees. The final score varies between the two tools and the category of each score is different. However, they both will potentially result in similar outcomes and recommendations.

The BRIEF survey has the ability to evaluate more risk factors than the RULA and REBA surveys. The risk factors that the BRIEF survey evaluates are repetition, duration, force, awkward posture, vibration, low temperature, soft tissue compression, and impact stress. However, in this study it is not prudent to evaluate vibration, low temperature, soft tissue compression, and impact stress because of the working conditions and the tasks being performed by Company XYZ's employees on the assembly lines.

Data Collection Procedures

Once the task analysis was conducted by the author and analyzed by the safety director of Company XYZ and the author, the employees on the two cells with the highest exposure potential were selected for further analysis. One additional cell that the safety director of Company XYZ was particularly concerned with, because of the number of "past complaints", was also identified and selected for further analysis. The three employees working on the chosen cells were then observed while all three ergonomic tools (RULA, REBA, and BRIEF) were completed to assess their body movements and the potential exposure to specific risk factors while completing the task. These surveys need little to no training in order to use them properly and to produce measurable quantitative data.

Data Analysis

The data from the task analysis was analyzed by the safety director at Company XYZ and the author. Based on the findings the two selected the specific cells that were analyzed further using the ergonomic tools identified. The data collected from using the task analysis was analyzed by identifying the number of potential ergonomic risk factors present as well as what the author and safety director defined as the most severe risk factors. For example, during the assembly of an engine at one of the chosen cells the worker was identified as using a pinch grip in repetition, ulnar deviation of both wrists in repetition, flexion of the back, reaching above shoulder height, etc. The data from the ergonomic tools (RULA, REBA, and BRIEF surveys) was assessed using the tables on the individual worksheets of each specific tool. By identifying what the different movements, locations, and angles the different body parts have to be extened or flexed at in order to perform the specific tasks observed, a number is assigned that is used to evaluated the final score for the task according to which ergonomic tool is used (RULA or REBA). The BRIEF survey is completed by identifying the various movements, location, and angles of the body parts. However, instead of a number score there is a risk rating that is assigned to the task. This risk rating is categorized as low, medium, or high risk depending on how many boxes of the survey are checked in each category.

Limitations of the study

Key limitations of the study's methodology include:

- The specific number of large and small engines varies from day-to-day operations. There is no way of telling how many large engines will be produced in any certain day, as well as the number of smaller engines. For example, the number of large and small engines will vary the repetition a worker will be exposed to at a specific height when assembling the small engine, which will change from day-to-day, thus potentially changing the numbers and outcomes of the REBA, RULA, and BRIEF surveys. Therefore, trying to determine the exact frequency of adjusting from the small engines to the large engines and vise versa throughout a "typical" day is very hard to estimate.

- This research paper will focus on only three different cells or stations on the assembly line and therefore will not evaluate the entire engine assembly line, in which there are many cells. Since workers rotate between a couple of different cells within the block (there are anywhere from seven to ten cells per block) the full ergonomic exposure to one employee over the course of a working shift will not be determined, only the risk factors at the specific cells observed will be determined.

Chapter IV: Results

Introduction

The purpose of this study was to evaluate the ergonomic risk factors that are present at Company XYZ in three of their many cells on a fixed assembly line that produces two different sized engines. The goals of the study were:

1. Conduct a task analysis of three blocks on the existing assembly line and identify three cells (stations) to be further analyzed using various ergonomic tools
2. Measure, using different ergonomic testing tools, the extent of the exposure as well as the location of the body most exposed at these cells
3. Identify ergonomic exposures that could potentially lead to cumulative trauma disorders (CTD)

This chapter includes the results of the task analysis performed for the three identified cells that was conducted by observing the processes performed by the workers on the engine assembly line, the results of the three ergonomic surveys, and a discussion and interpretation of these results.

Determining the cells with the highest ergonomic risk factors

In order to achieve the first goal a task analysis was conducted to identify the two cells with the most potential of having ergonomic risk factors that would contribute or could potentially lead to the development of a cumulative trauma disorder. Once these two cells were identified a third cell was identified because it was one of particular concern to the safety director of Company XYZ. Each of the identified stations were then analyzed by completing three ergonomic surveys (RULA, REBA, and BRIEF) for each cell for both the small engine and the large engine. The differences between the small and large engines assembly at each of the cells were very minimal because the worker was performing the same actions only on different sized engines. The cells that were selected for analysis were cell 2080, cell 2090, and cell 2200. During the assembly process of the large engine, cell 2080 is performed as a pre-assembly task and therefore is not performed on the assembly line when manufacturing.

Ergonomic Task Analysis of Cell 2080

The tasks performed by a worker at cell 2080 in the blue block for the small engine are as followed:

- Reach up to 46 inches high to access the 7.5 pound cylinder head from totes stacked up to three platforms high on a cart at 13 inches high
- Assemble and press valve seals into cylinder head on the line table (35 inches high)
- Reach to 22 inches for springs and retainers with pinch grip
- Assemble while flexing trunk on assembly line at 35 inches
- Install components using the press

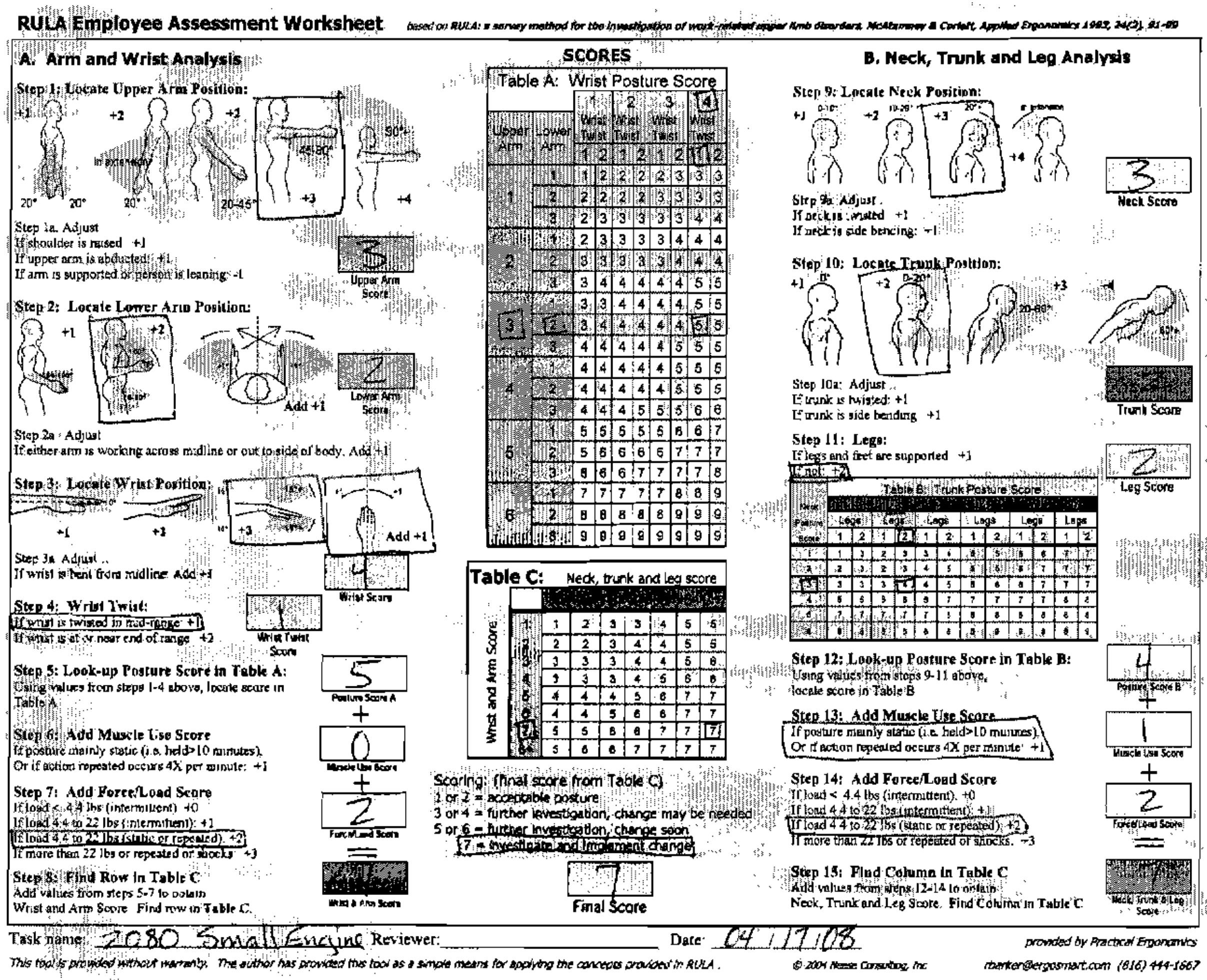
The physical demands that must be met of the employee to perform the tasks at cell 2080 on the small engine include:

- Frequent flexing of trunk and lifting
- Frequent reaching to shoulder height
- Frequent pinch grip and deviation of the wrists
- Constant standing
- Frequency of these tasks is approximately 50 times per hour

Ergonomic Tools of cell 2080 for the small engine

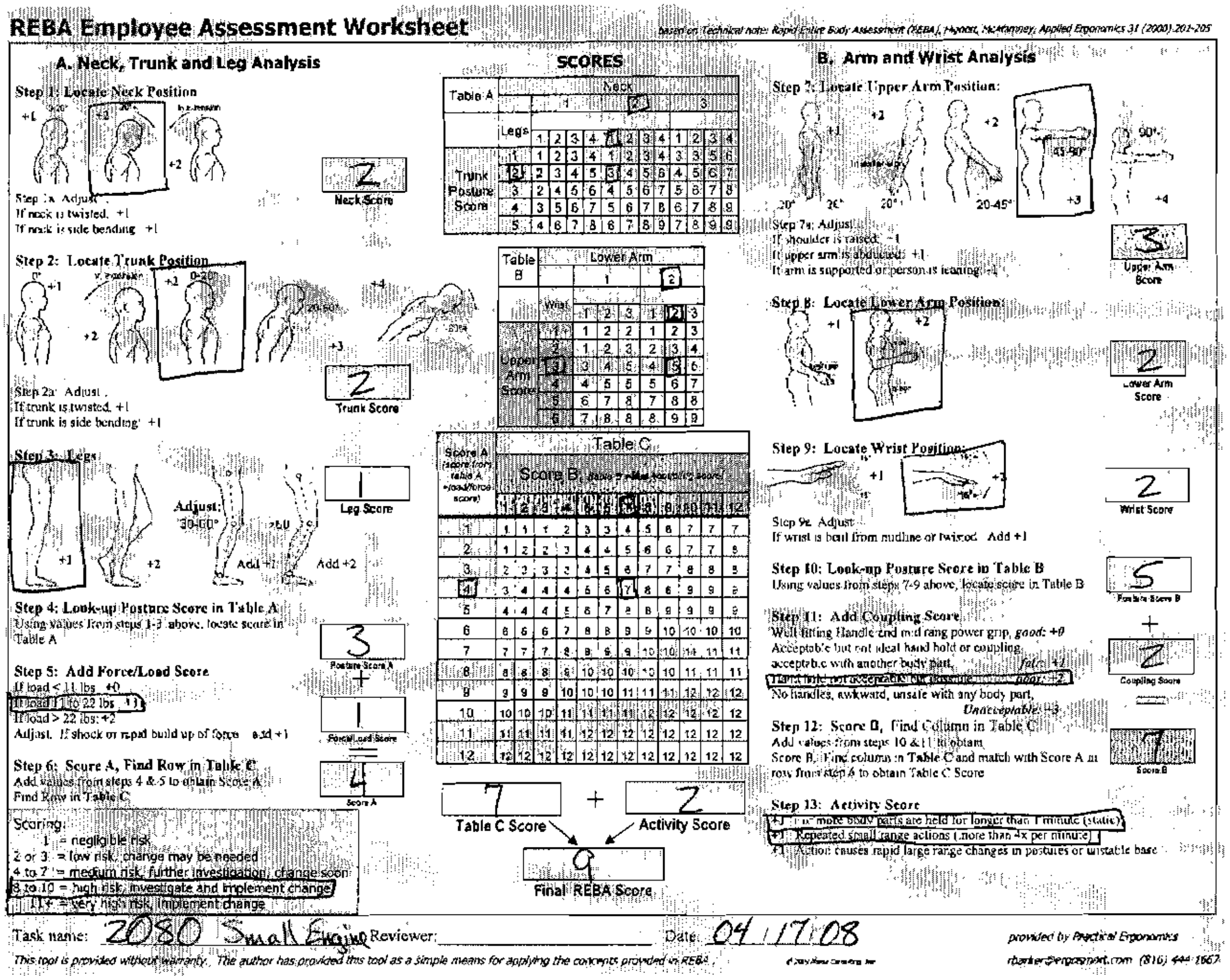
The Figures below show the three ergonomic surveys for cell 2080. Figure 1 is of the Rapid Upper Body Assessment (RULA) survey, Figure 2 is of the Rapid Entire Body Assessment (REBA) survey, and Figure 3 is of the BRIEF survey.

Figure 1 – RULA survey of cell 2080 for the small engine



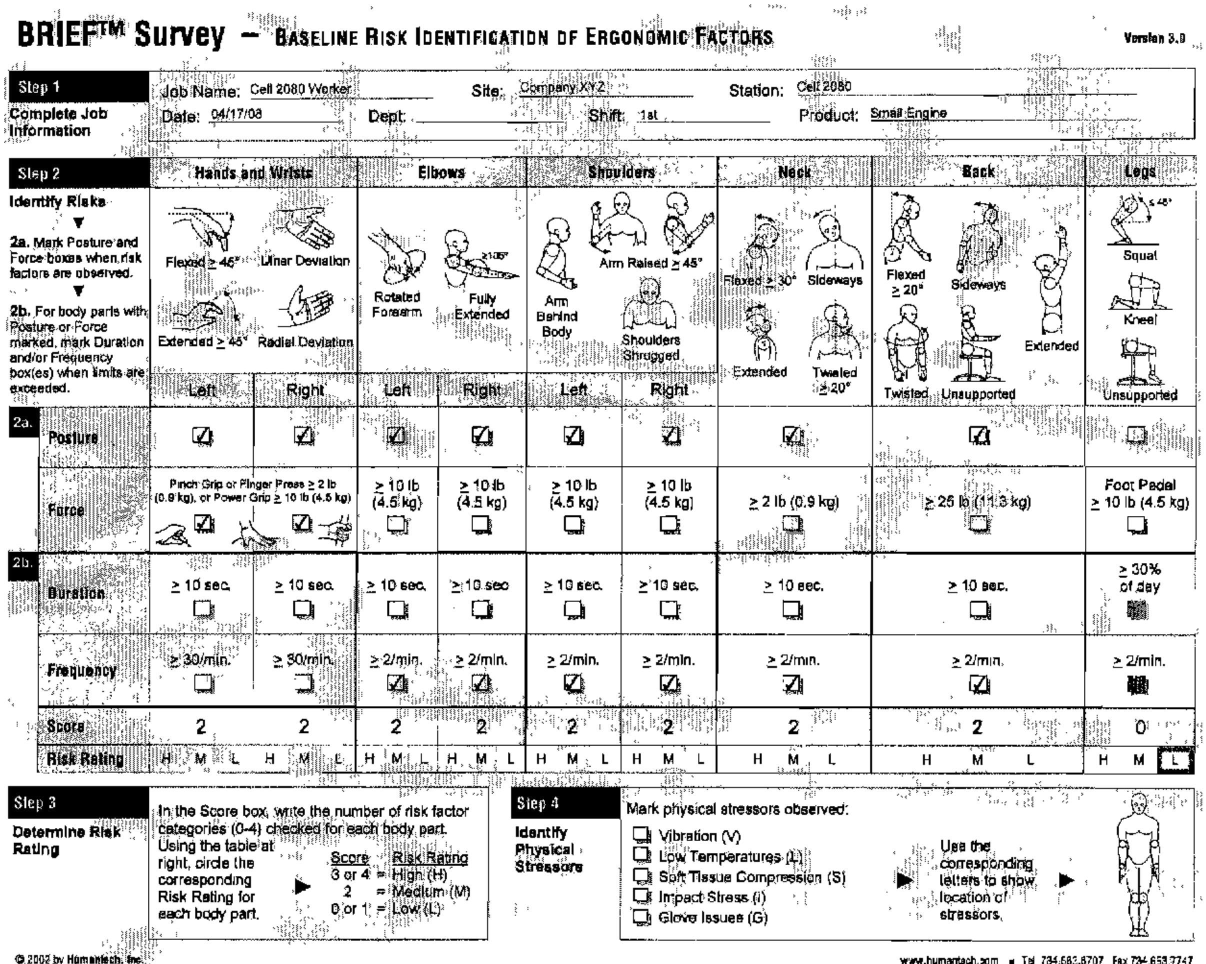
The RULA assessment identified there was a concern for the worker's arms, wrists, neck, and trunk position while completing the tasks at cell 2080. The resulting score of the arm and wrist analysis was a seven, and the score for the neck, trunk, and leg analysis resulted in a score of seven. When put into the final table the final score of the RULA survey was a seven, which means "investigate and implement change".

Figure 2 – REBA survey of cell 2080 for the small engine



The REBA assessment is similar to the RULA in that most of the upper body risk factors have been identified, but the REBA also assesses parts of the lower body as well. This score is calculated from the overall score of the neck, trunk, and legs analysis resulting in a four and the score of the arm and wrist analysis resulting in a seven. From there the numbers are placed into Table C of the survey (which resulted in a seven) and two more points are added as a result of the "activity score". These are from "1 or more body parts are being held for longer than 1 minutes", and "Repeated small range action", thus resulting in a final score of nine. The final REBA score of nine means "high risk, investigate and implement change".

Figure 3 – BRIEF survey of cell 2080 for the small engine



Through completion of the BRIEF survey, the ergonomic risk factors that were identified are force on both hands and wrists, high frequency of rotation in both forearm and fully extended elbows, arms raised more than two times per minute, frequent neck flexion, and frequent flexion of the back and trunk. Each check mark represents one point in the identified section of the analysis. This resulted in the risk rating of Medium (M) for all parts of the body identified on the survey except for the legs. A medium score is the result of two checks in the column, or body part.

Ergonomic Task Analysis for Cell 2090

The second cell that was analyzed with the three ergonomic survey tools was cell 2090. The tasks performed by a worker at cell 2090, which is the station right after 2080 and still in the blue block, are as follows:

- Reach over a box of bolts (approx. 16 inches) for a pinch grip on a 9 pound cylinder head
- Install long bolts (ulnar wrist deviation) with reaches to the top of the small engine (51 inches high), large engine (58 inches)
- Apply serial number decal and scan
- Torque head bolts using multi-spindle power head with a reach of 68 inches
- Reach 56 inches to access gasket

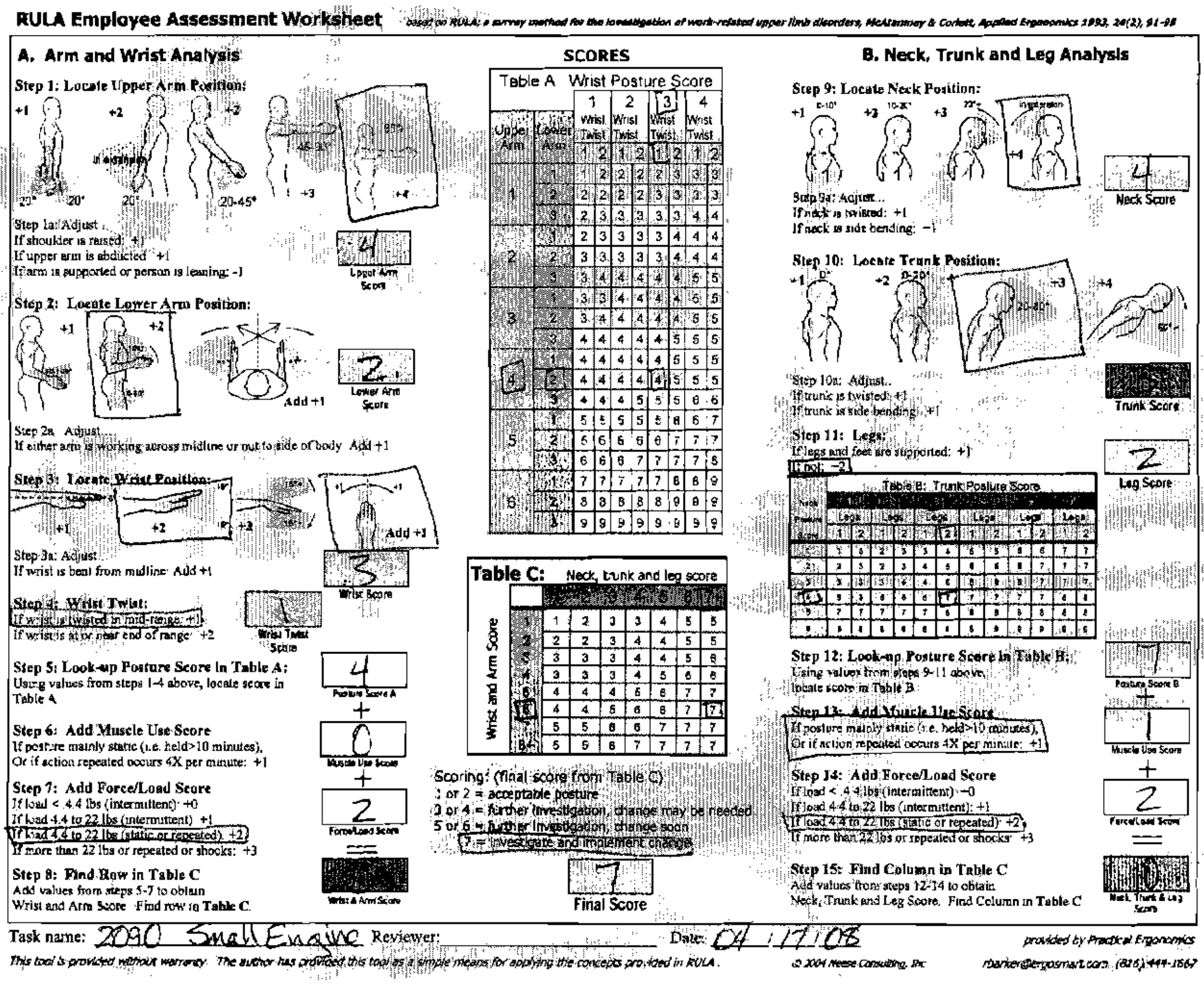
The physical demands that must be met of the employee in order to perform the tasks at cell 2090 for both the small and large engines include:

- Frequent forward reach above shoulder height
- Frequent pinch grip and lift of 9 pound cylinder head
- Frequent flexion of the trunk to reach engine
- Constant standing
- Frequency of these tasks is approximately 50 times per hour

Ergonomic Tools for Cell 2090 for the small engine

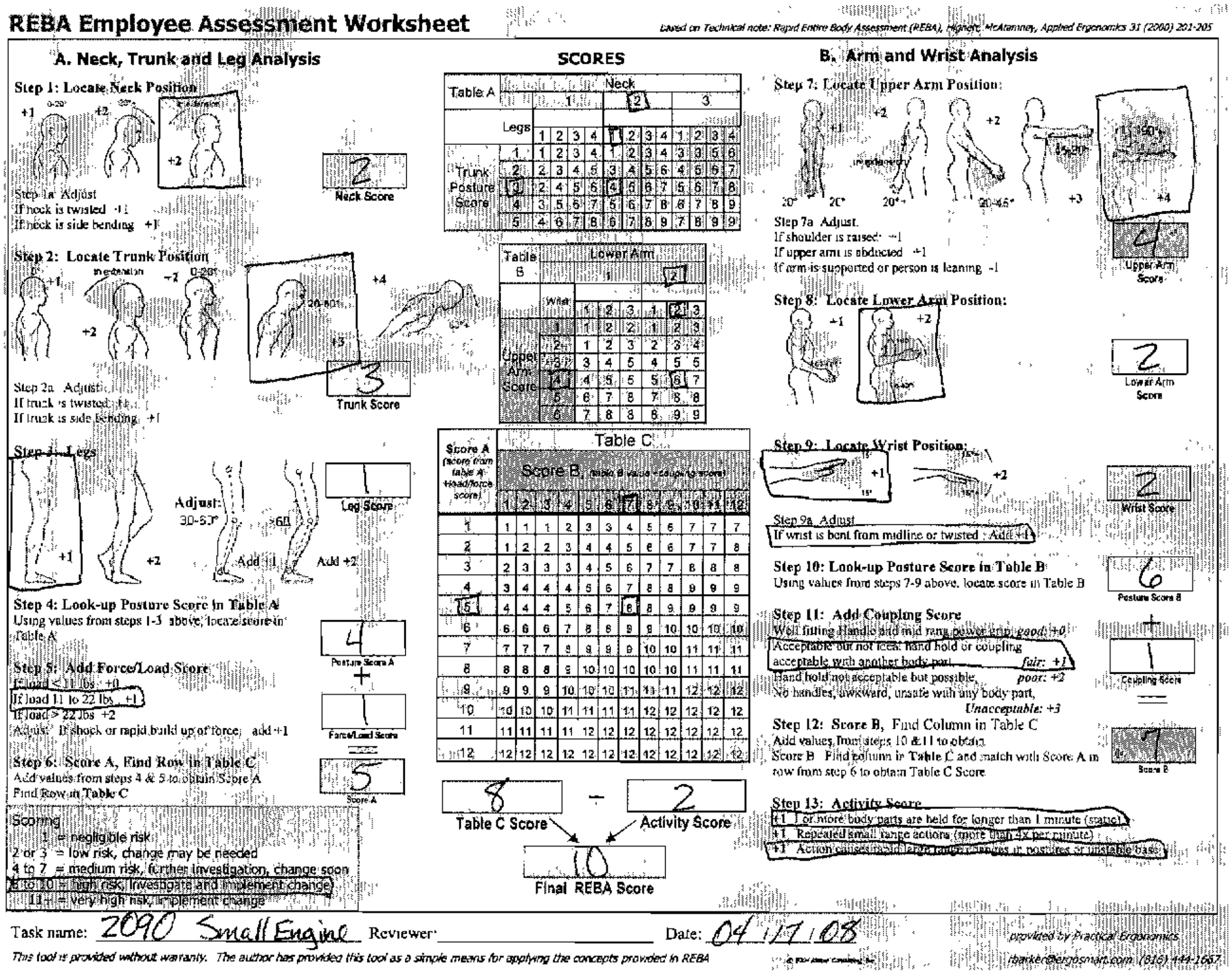
The second station that was assessed using the three ergonomic surveys was cell 2090. For Cell 2090, the ergonomic surveys were completed for both the small engine and the larger sized engine. Therefore, Figures 4, 5, and 6 are results from the small engine and Figures 7, 8, and 9 are results from the large engine.

Figure 4 – RULA survey for cell 2090 for the small engine



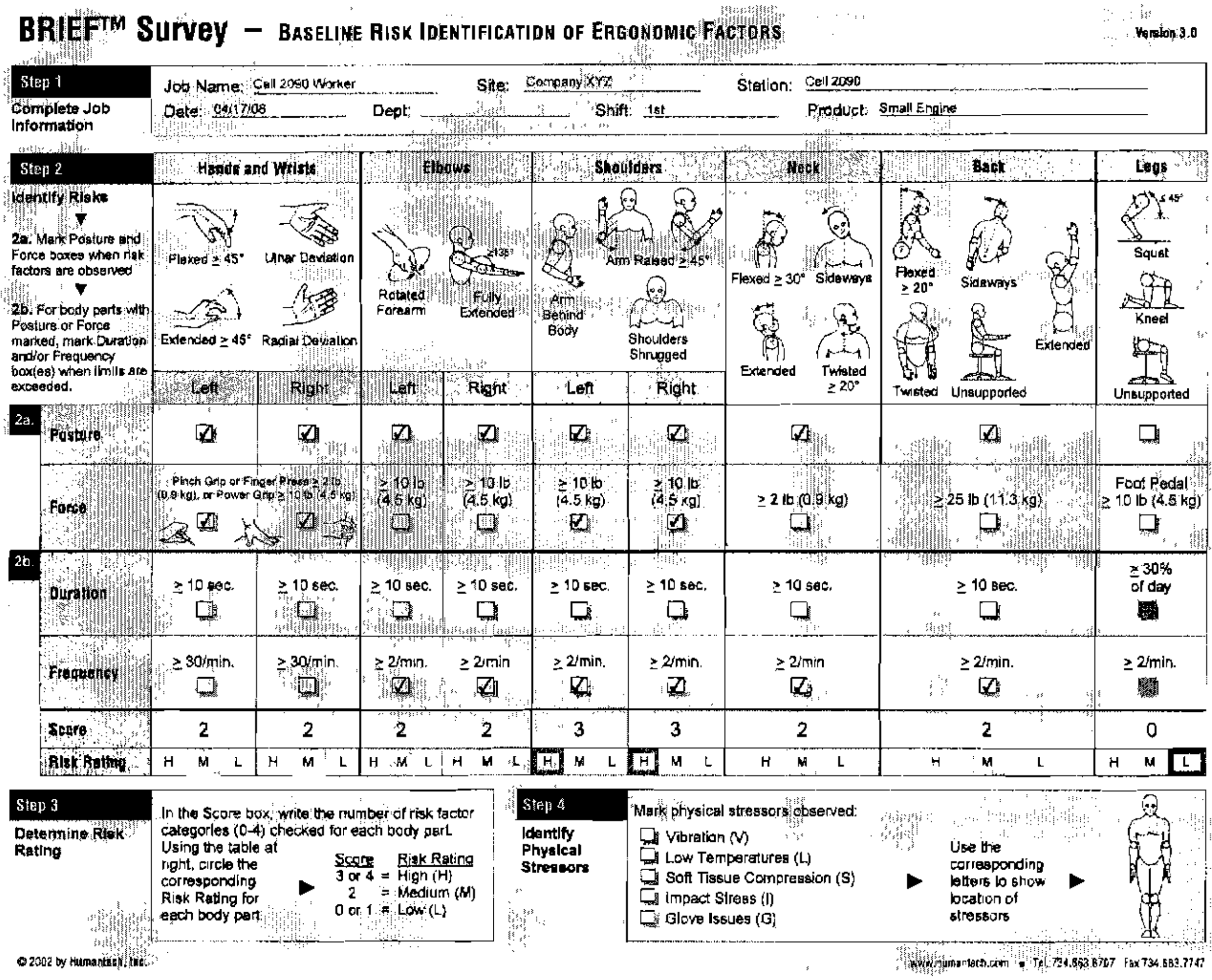
The RULA survey that was completed for cell 2090 identified that there were ergonomic risk factors in the frequent extension of the neck, frequent reaching of the upper arms higher than 90 degrees, and frequent flexion of the trunk. The final score of the RULA survey was seven, which means, "investigate and implement change". This was the result from Table C in Figure 4, which resulted in an arm and wrist analysis score of six and a neck, trunk, and leg analysis score of ten.

Figure 5 – REBA survey of cell 2090 for the small engine



The score of the REBA survey is calculated from the overall score of the neck, trunk, and legs analysis resulting in a five and the score of the arm and wrist analysis resulting in a seven. From there the numbers are placed into Table C of the survey (which resulted in an eight) and two more points are added as a result of the "activity score". These are from "1 or more body parts are being held for longer than 1 minutes", and "Action causes rapid large range changes in postures or unstable base", thus resulting in a final score of ten. The final REBA score of ten means "high risk, investigate and implement change".

Figure 6 – BRIEF survey of cell 2090 for the small engine



BRIEF™ Survey – Baseline Risk Identification of Ergonomic Factors Version 3.0

Step 1 Complete Job Information — Job Name: Cell 2090 Worker; Site: Company XYZ; Station: Cell 2090; Date: 04/17/08; Dept: ; Shift: 1st; Product: Small Engine

Step 2 Identify Risks — 2a. Mark Posture and Force boxes when risk factors are observed. 2b. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

	Hands and Wrists Left	Hands and Wrists Right	Elbows Left	Elbows Right	Shoulders Left	Shoulders Right	Neck	Back	Legs
Posture	Flexed ≥ 45°, Ulnar Deviation, Extended ≥ 45°, Radial Deviation		Rotated Forearm, Fully Extended		Arm Behind Body, Arm Raised ≥ 45°, Shoulders Shrugged		Flexed ≥ 30°, Sideways, Extended, Twisted ≥ 20°	Flexed ≥ 20°, Sideways, Extended, Twisted, Unsupported	Squat, Kneel, Unsupported
2a. Posture	☑	☑	☑	☑	☑	☑	☑	☑	☐
Force	Pinch Grip or Finger Press ≥ 2 lb (0.9 kg), or Power Grip ≥ 10 lb (4.5 kg) ☑	☑	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☑	≥ 10 lb (4.5 kg) ☑	≥ 2 lb (0.9 kg) ☐	≥ 25 lb (11.3 kg) ☐	Foot Pedal ≥ 10 lb (4.5 kg) ☐
2b. Duration	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 30% of day ■
Frequency	≥ 30/min. ☐	≥ 30/min. ☐	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min. ■
Score	2	2	2	2	3	3	2	2	0
Risk Rating	H M L	H M L	H M L	H M L	**H** M L	**H** M L	H M L	H M L	H M **L**

Step 3 Determine Risk Rating — In the Score box, write the number of risk factor categories (0-4) checked for each body part. Using the table at right, circle the corresponding Risk Rating for each body part. Score / Risk Rating: 3 or 4 = High (H); 2 = Medium (M); 0 or 1 = Low (L)

Step 4 Identify Physical Stressors — Mark physical stressors observed: ☐ Vibration (V) ☐ Low Temperatures (L) ☐ Soft Tissue Compression (S) ☐ Impact Stress (I) ☐ Glove Issues (G). Use the corresponding letters to show location of stressors

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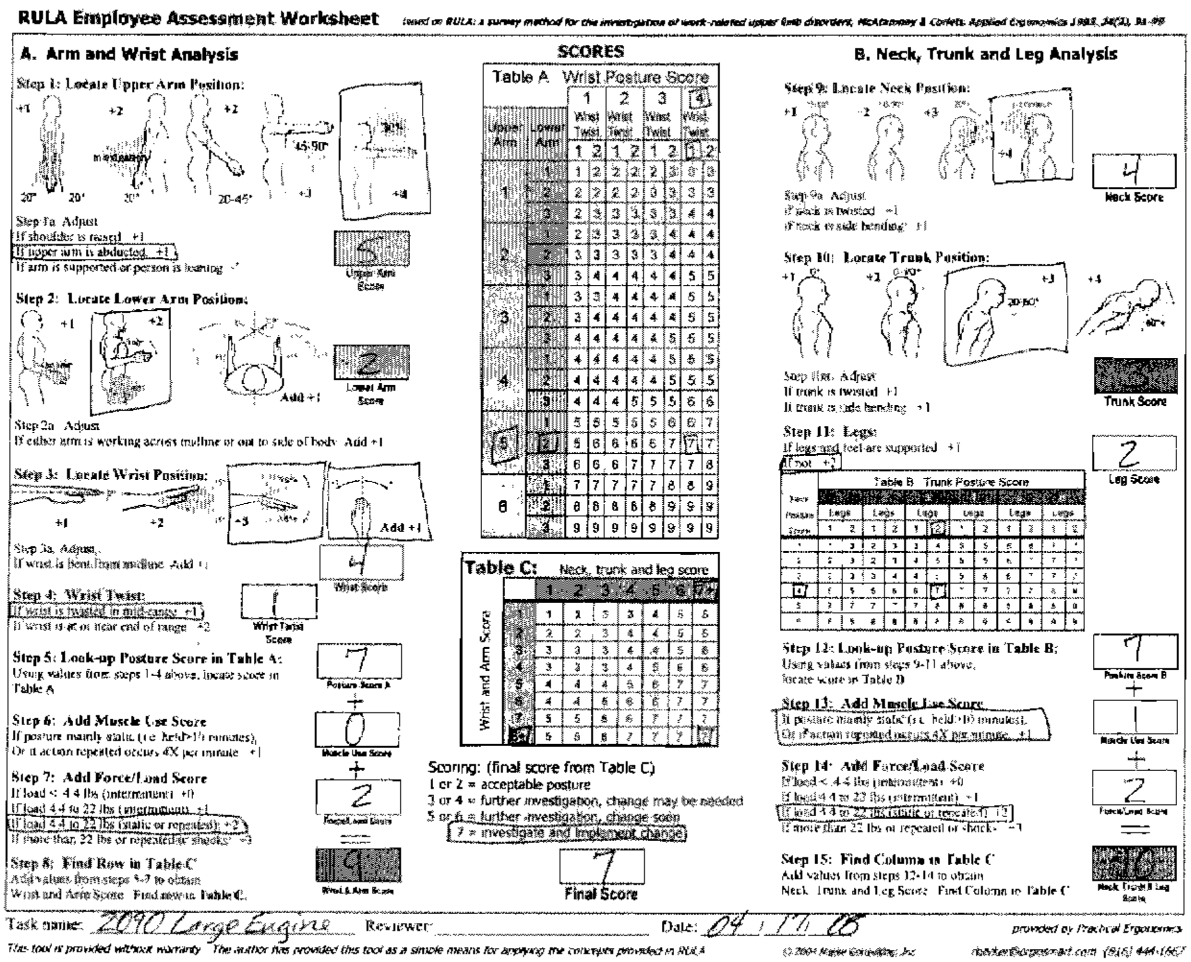
Upon completion of the BRIEF survey of cell 2090 for the small engine, the ergonomic risk factors are apparent. The highest risk rating, as a result of the completion of the BRIEF survey, was high (H) in both of the shoulders, and medium (M) in both hands and wrists, both elbows, the neck, and the back. The reason both shoulders resulted in a risk rating of high is because of the posture, force of pulling down the machine from over head height, and having a frequency of more than two times per minute. Again, each check mark in a column represents one point in the identified section of the analysis, which results in the BRIEF score.

Ergonomic Tools for Cell 2090 for the large engine

The next three surveys were conducted while observing the assembly in cell 2090 but the observation was taken while the large engine was being assembled instead of the small engine. The three surveys were similar in that the same risk factors were present, but the extent of the risk factors increased a little except where the results have already identified the risk factors as "high".

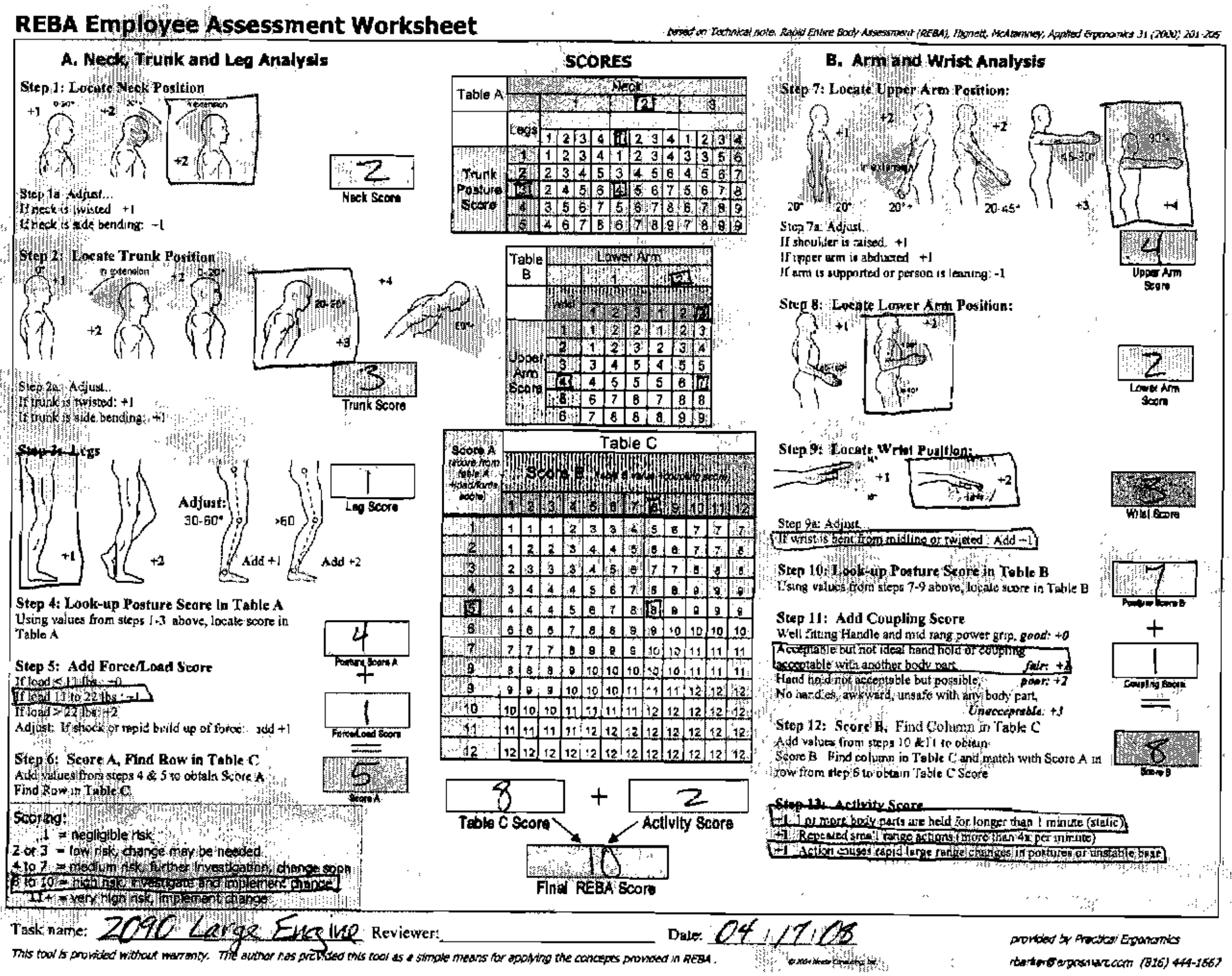
Figure 7 – RULA survey of cell 2090 for the large engine



As compared to Figure 4, the ergonomic risk factors identified were the same because this was the same task, yet the extent to each of the risk factors was a little more extreme, resulting in higher scores. The main differences occur on the right side of

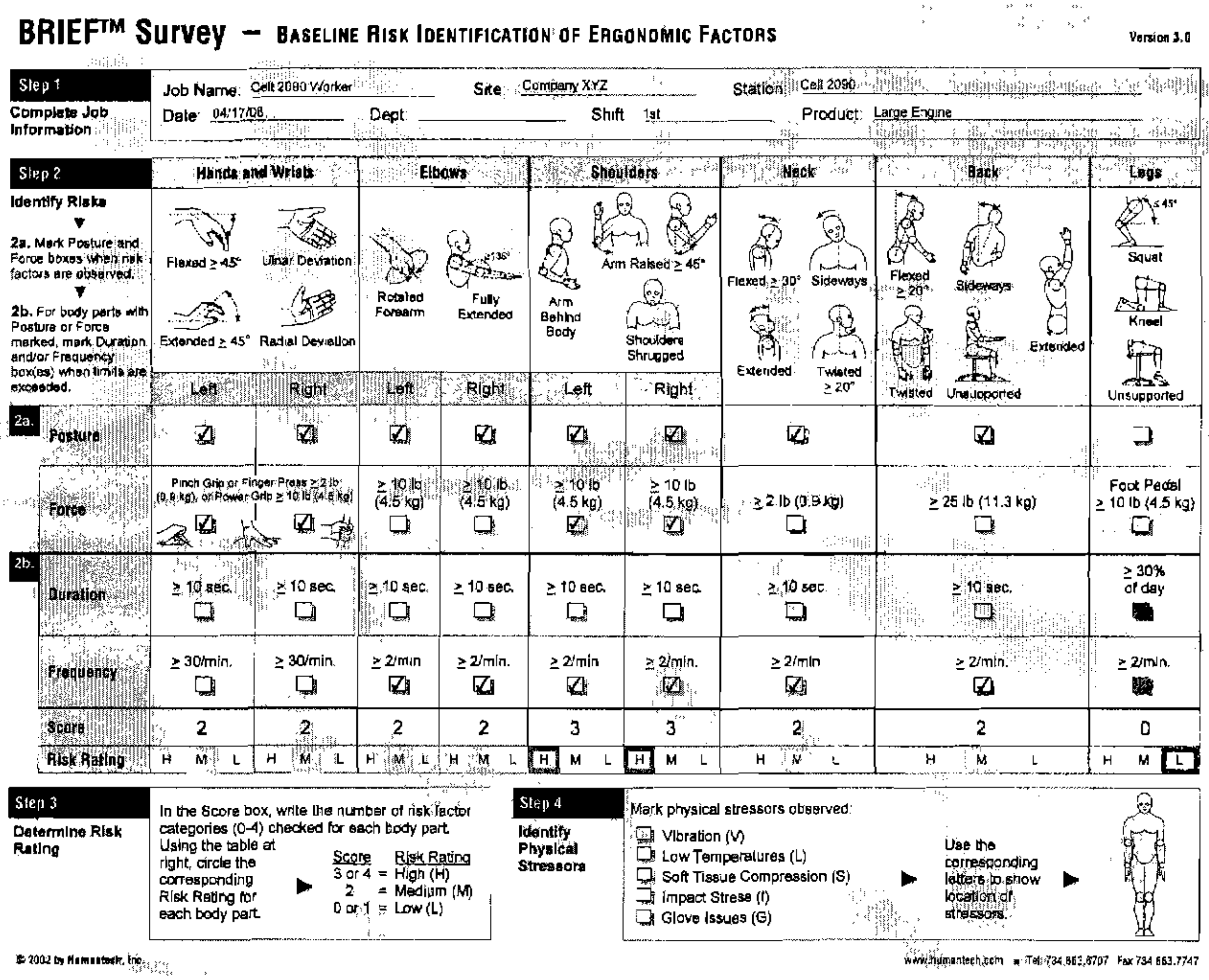
Figure 7 as compared to Figure 4. Step 1: locate upper arm position analysis resulted in a score of five, and step 3: locate wrist position resulted in a score of 4 as opposed to the three score from the small engine. These two changes resulted in a score of nine, as opposed to the six in Figure 4, in the wrist and arm score. The final RULA score however, did not change because the highest score possible is a seven, which was the resulting score of Figure 4. The RULA survey of cell 2090 when assembling the large engine thus resulted in "investigate and implement change."

Figure 8 – REBA survey of cell 2090 for the large engine



The only difference between the REBA survey in cell 2090 in the small engine and the large engine is step 9: locate wrist position. This is due to the worker performing the tasks at cell 2090, which requires a greater angle of deviation from the neutral position that the small engine requires. The wrist extension and flexion while assembling the larger engine requires an angle of greater than 15 degrees, therefore a score of three was assigned for step 9: locate wrist position. Overall though, the final REBA score is still a ten, like in Figure 4, which again means "high risk, investigate and implement change".

Figure 9 – BRIEF survey of cell 2090 for the large engine



BRIEF™ Survey – Baseline Risk Identification of Ergonomic Factors Version 3.0

Step 1 — Complete Job Information

Job Name: Cell 2090 Worker   Site: Company XYZ   Station: Cell 2090

Date: 04/17/08   Dept: Shift: 1st   Product: Large Engine

Step 2 — Identify Risks

2a. Mark Posture and Force boxes when risk factors are observed.

2b. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

	Hands and Wrists: Left	Hands and Wrists: Right	Elbows: Left	Elbows: Right	Shoulders: Left	Shoulders: Right	Neck	Back	Legs
Posture descriptors	Flexed ≥ 45°, Ulnar Deviation, Extended ≥ 45°, Radial Deviation		Rotated Forearm, Fully Extended		Arm Behind Body, Arm Raised ≥ 45°, Shoulders Shrugged		Flexed ≥ 30°, Sideways, Extended, Twisted ≥ 20°	Flexed ≥ 20°, Sideways, Extended, Twisted, Unsupported	Squat, Kneel, Unsupported
2a. Posture	☑	☑	☑	☑	☑	☑	☑	☑	☐
Force	Pinch Grip or Finger Press ≥ 2 lb (0.9 kg), or Power Grip ≥ 10 lb (4.5 kg) ☑	☑	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☑	≥ 10 lb (4.5 kg) ☑	≥ 2 lb (0.9 kg) ☐	≥ 25 lb (11.3 kg) ☐	Foot Pedal ≥ 10 lb (4.5 kg) ☐
2b. Duration	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 30% of day ■
Frequency	≥ 30/min. ☐	≥ 30/min. ☐	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min. ■
Score	2	2	2	2	3	3	2	2	0
Risk Rating	H M L	H M L	H M L	H M L	**H** M L	**H** M L	H M L	H M L	H M **L**

Step 3 — Determine Risk Rating

In the Score box, write the number of risk factor categories (0-4) checked for each body part. Using the table at right, circle the corresponding Risk Rating for each body part.

Score	Risk Rating
3 or 4	= High (H)
2	= Medium (M)
0 or 1	= Low (L)

Step 4 — Identify Physical Stressors

Mark physical stressors observed:

- ☐ Vibration (V)
- ☐ Low Temperatures (L)
- ☐ Soft Tissue Compression (S)
- ☐ Impact Stress (I)
- ☐ Glove Issues (G)

Use the corresponding letters to show location of stressors.

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The results from the BRIEF survey for cell 2090 while manufacturing the large engine were the same as the results from the small engine. As opposed to the RULA and REBA surveys, the BRIEF categorizes wrist posture from 0 to 45 degrees as an ergonomic risk factor and not 0 to 15 degrees for one point and greater than 15 degrees for two points. Therefore, the extra flexion and extension as described with Figures 7 and 8 in the RULA and REBA surveys for the large engine is not identified in the BRIEF survey. The overall risk rating of cell 2090 for the large engine are the same as the ratings for the small engine in Figure 6, which includes; "high" for both shoulders, "medium" for both hands and wrists, both elbows, neck, and back.

Ergonomic Task Analysis of Cell 2200

The last cell that was analyzed using the three ergonomic tools (RULA, REBA, and BRIEF surveys) was cell 2200. This cell is futher down the assembly line (eleven cells down from cell 2090), in a different block. The tasks performed by a worker at cell 2200, of the yellow block are as follows:

- Apply grease to valve tips
- Grasp push rods from box with trunk twist to the left of the employee at 34 inches
- Install push rods by reaching forward 13 inches (flexion of the trunk) at 52 inches high for the small engine and 59 inches for large engine
- Turn around to grasp rocker arms from rack (adjustable height) and assemble (ulnar wrist deviation) at 52 inches high for small engine and 59 inches for the large engine
- Reach 61 inches for the DC tool and torque rocker arms

The physical demands that must be met of the employee to perform the tasks at cell 2200 on the small and large engine include:

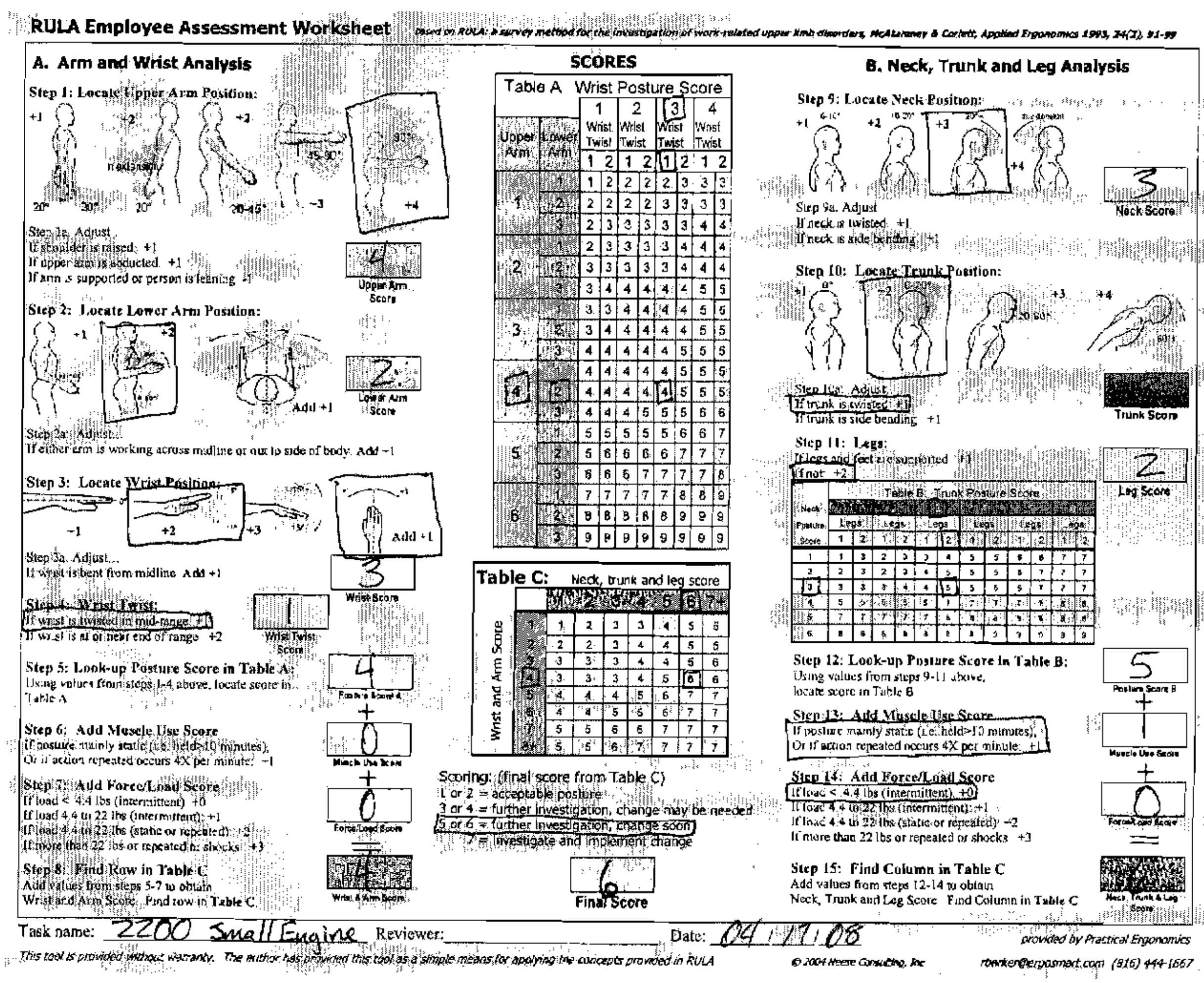
- Occasional twisting of the trunk

- Frequent work above shoulder height
- Frequent pinch grip
- Frequent ulnar deviation of the wrists
- Constant standing
- Frequency of these tasks is approximately 50 times per hour

Ergonomic Tools for Cell 2200 for the small engine

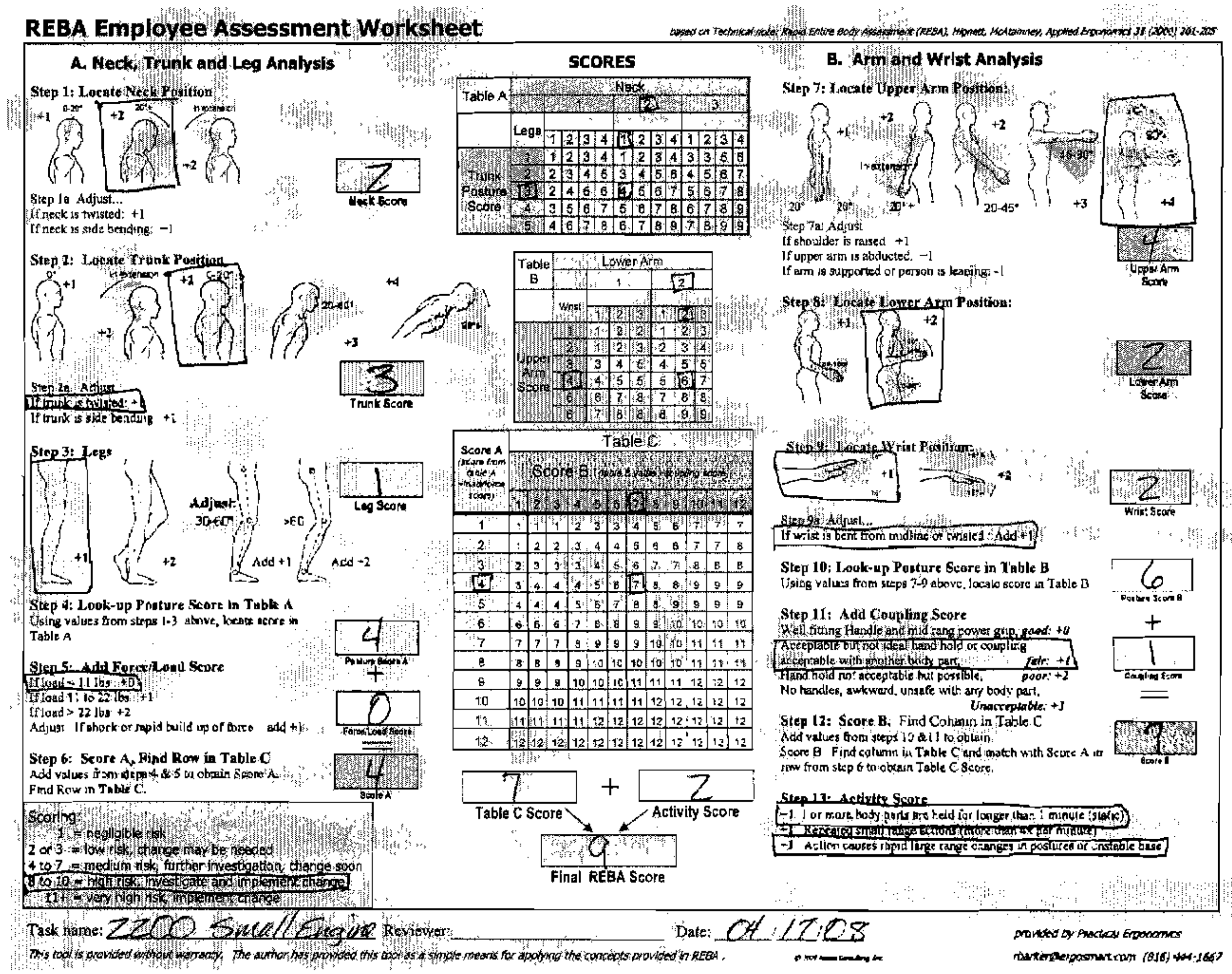
The three ergonomic tools were completed for cell 2200 involving both the small engine and the large engine. The results of these surveys as well as a description of the observations are listed in this section.

Figure 10 – RULA survey of cell 2200 for the small engine



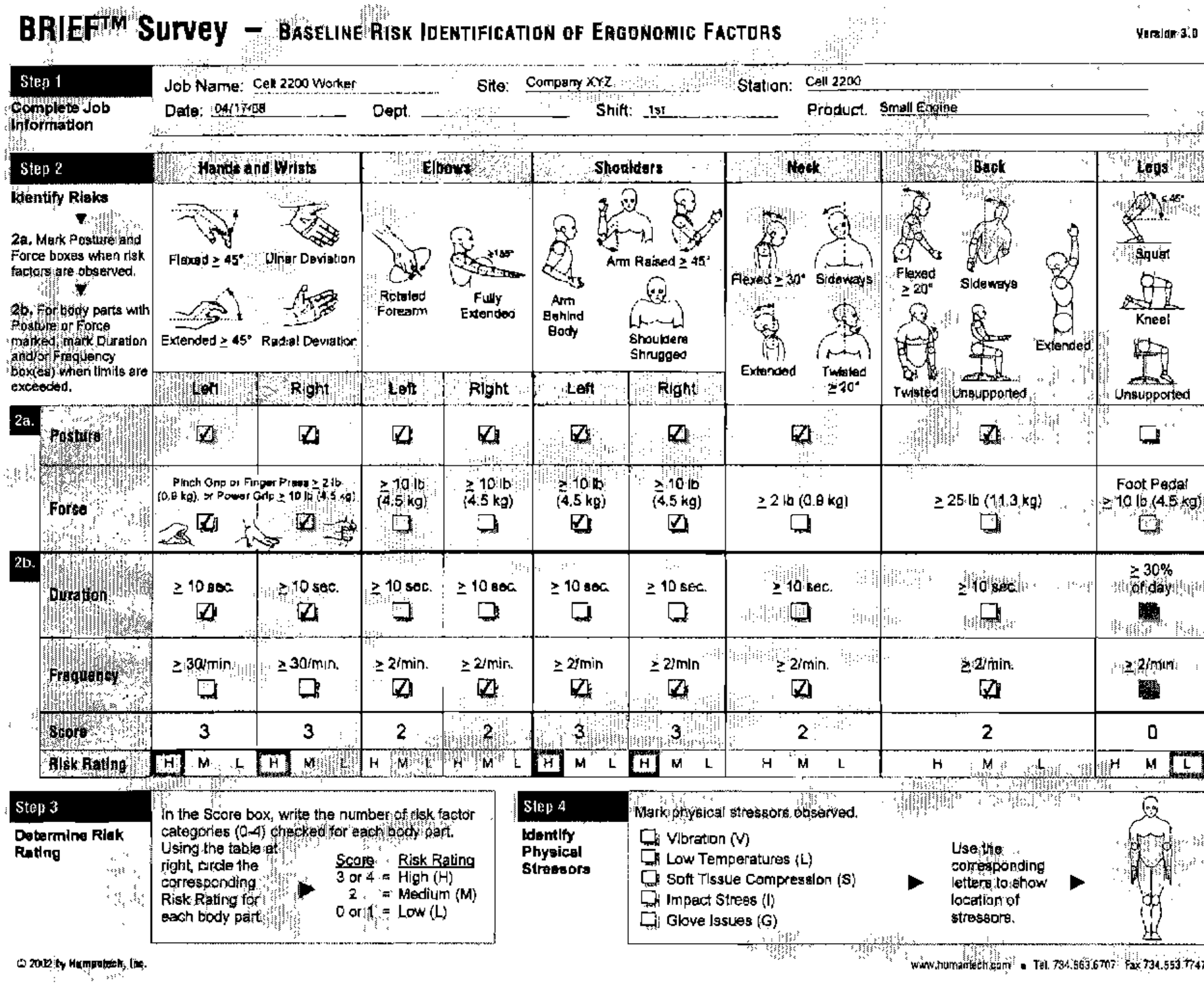
The tasks that were performed at cell 2200 requires the worker to frequently raise their arms above shoulder height in order to engage the DC torque machine, which results in the indication of arms raised higher than 90 degrees on the RULA survey. The trunk and neck positioning were also two of the areas that were identified in this survey as having a higher risk factor score (3) because of the flexion and the frequent twisting of the trunk. There is no heavy lifting required at this cell and therefore there were no added force/load adjustments in the scores on either side of the RULA survey. The arm and wrist analysis resulted in a score of four and the neck, trunk, and leg analysis resulted in a score of six. Then these numbers were input in to the Table C in Figure 10, this resulted in a final RULA score of six, which means “further investigation, change soon”.

Figure 11 – REBA survey of cell 2200 for the small engine



The REBA survey was completed after the RULA survey. The two were similar in that they focus on many of the same body parts like the other two cells, but they were still somewhat different. Because of the tasks performed at cell 2200, the REBA score identified a high risk rating in step 2: locate trunk position, and step 7: locate upper arm position. The REBA score from Table C on Figure 11 resulted in a seven, but the activity score added two more points, thus making the final REBA score a nine. A nine REBA score means "high risk, investigate and implement change." The reason for the activity score was that "one or more body parts are held for longer than one minute" and "action causes rapid large range changes in posture or unstable base."

Figure 12 – BRIEF survey of cell 2200 for the small engine



BRIEF™ Survey – Baseline Risk Identification of Ergonomic Factors Version 3.0

Step 1 Complete Job Information — Job Name: Cell 2200 Worker Site: Company XYZ Station: Cell 2200 Date: 04/17/08 Dept. Shift: 1st Product: Small Engine

Step 2 Identify Risks — 2a. Mark Posture and Force boxes when risk factors are observed. 2b. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

	Hands and Wrists Left	Hands and Wrists Right	Elbows Left	Elbows Right	Shoulders Left	Shoulders Right	Neck	Back	Legs
Posture	Flexed ≥ 45°, Ulnar Deviation, Extended ≥ 45°, Radial Deviation		Rotated Forearm, Fully Extended		Arm Behind Body, Arm Raised ≥ 45°, Shoulders Shrugged		Flexed ≥ 30°, Sideways, Extended, Twisted ≥ 20°	Flexed ≥ 20°, Sideways, Twisted, Unsupported, Extended	Squat, Kneel, Unsupported
2a. Posture	☑	☑	☑	☑	☑	☑	☑	☑	☐
Force	Pinch Grip or Finger Press ≥ 2 lb (0.9 kg), or Power Grip ≥ 10 lb (4.5 kg) ☑	☑	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☑	≥ 10 lb (4.5 kg) ☑	≥ 2 lb (0.9 kg) ☐	≥ 25 lb (11.3 kg) ☐	Foot Pedal ≥ 10 lb (4.5 kg) ☐
2b. Duration	≥ 10 sec. ☑	≥ 10 sec. ☑	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 30% of day ■
Frequency	≥ 30/min. ☐	≥ 30/min. ☐	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min. ■
Score	3	3	2	2	3	3	2	2	0
Risk Rating	**H** M L	**H** M L	H M L	H M L	**H** M L	**H** M L	H M L	H M L	H M **L**

Step 3 Determine Risk Rating — In the Score box, write the number of risk factor categories (0-4) checked for each body part. Using the table at right, circle the corresponding Risk Rating for each body part.

Score	Risk Rating
3 or 4 =	High (H)
2 =	Medium (M)
0 or 1 =	Low (L)

Step 4 Identify Physical Stressors — Mark physical stressors observed.
☐ Vibration (V)
☐ Low Temperatures (L)
☐ Soft Tissue Compression (S)
☐ Impact Stress (I)
☐ Glove Issues (G)
Use the corresponding letters to show location of stressors.

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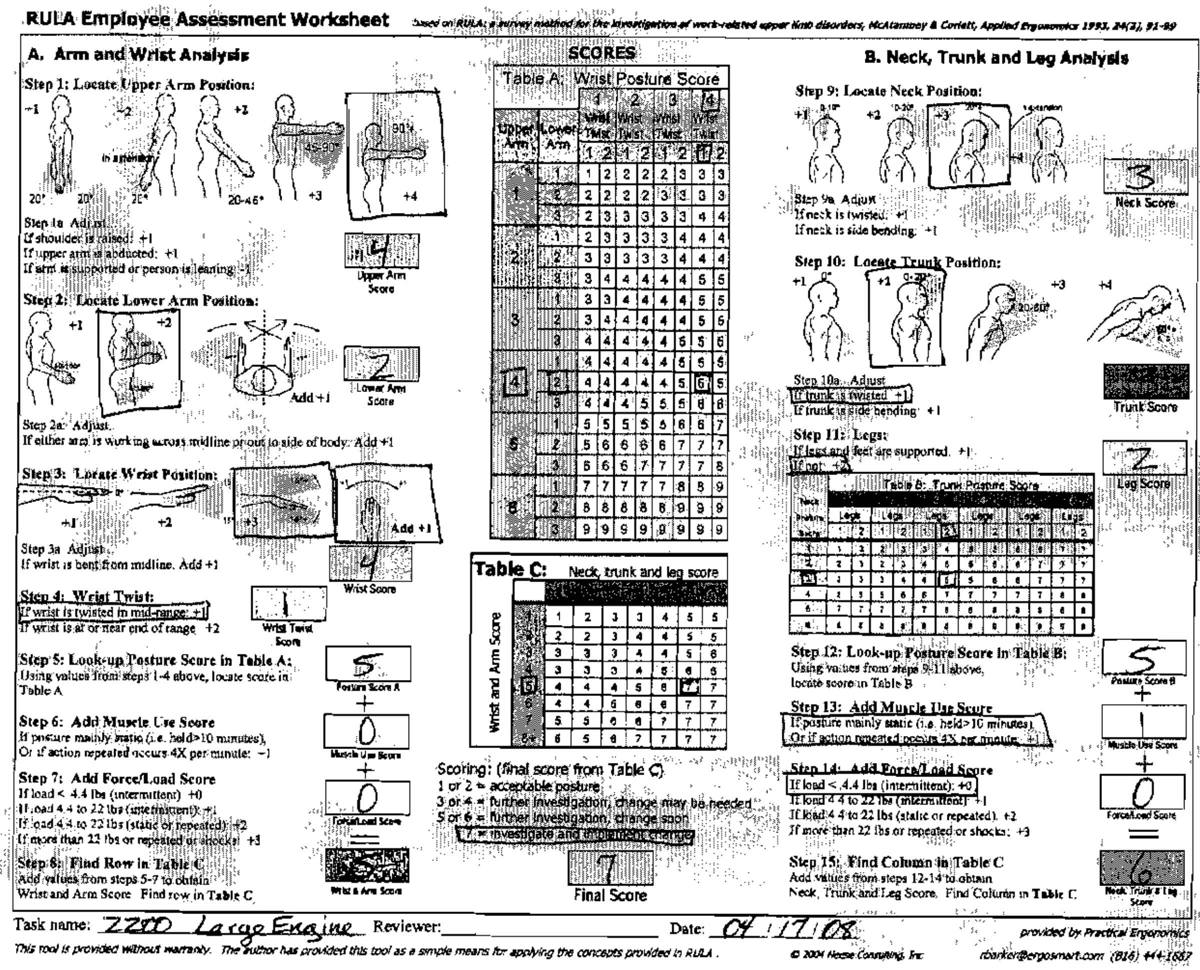
The BRIEF survey for cell 2200 assembling the small engine identified that there was a high ergonomic risk rating in both hands and wrists due to posture, force, and duration, and a high risk rating in both shoulders due to posture, force, and duration. Just like cell 2090, this was due to the frequent reaching over shoulder height to engage and pull down the DC torque tool. Both elbows were identified by the BRIEF survey because of posture and frequency.

Ergonomic Tools for Cell 2200 for the large engine

The three ergonomic tools were completed for cell 2200 involving the large engine, which are displayed and described in the next three figures. The results of the surveys completed while the worker was assembling the large engine were primarily the same, except for the wrist extension and flexion like in cell 2090. The larger size of the engine requires a greater angle of wrist deviation than that of the small engine. Otherwise, there was no other difference identified in the RULA, REBA, and BRIEF surveys as it relates to the assembly of the large engine compared to the small engine. Figures 13, 14, and 15 are shown and described below.

Figure 13 – RULA survey of cell 2200 for the large engine



Once again, it was observed that the only difference between Figure 13 and Figure 10 was step 3: locate wrist position. Manufacturing the large engine at cell 2200 required a greater angle of flexion in order to install the push rods required for this cell, this is apparent in Figure 13 (RULA) and Figure 14 (REBA). This changes the wrist and arm RULA score from a four in Figure 10 to a five in Figure 13. This resulted in a final RULA score of seven, which is "investigate and implement change". Figure 14 is a REBA survey that identified the same differences in wrist extension and flexion. The change in step 9: locate wrist position from Figure 11 to Figure 14 was the same difference previously stated for Figure 10 and Figure 13. This resulted in the final REBA score of ten in Figure 14, this means "high risk, investigate and implement change".

Figure 14 – REBA survey of cell 2200 for the large engine

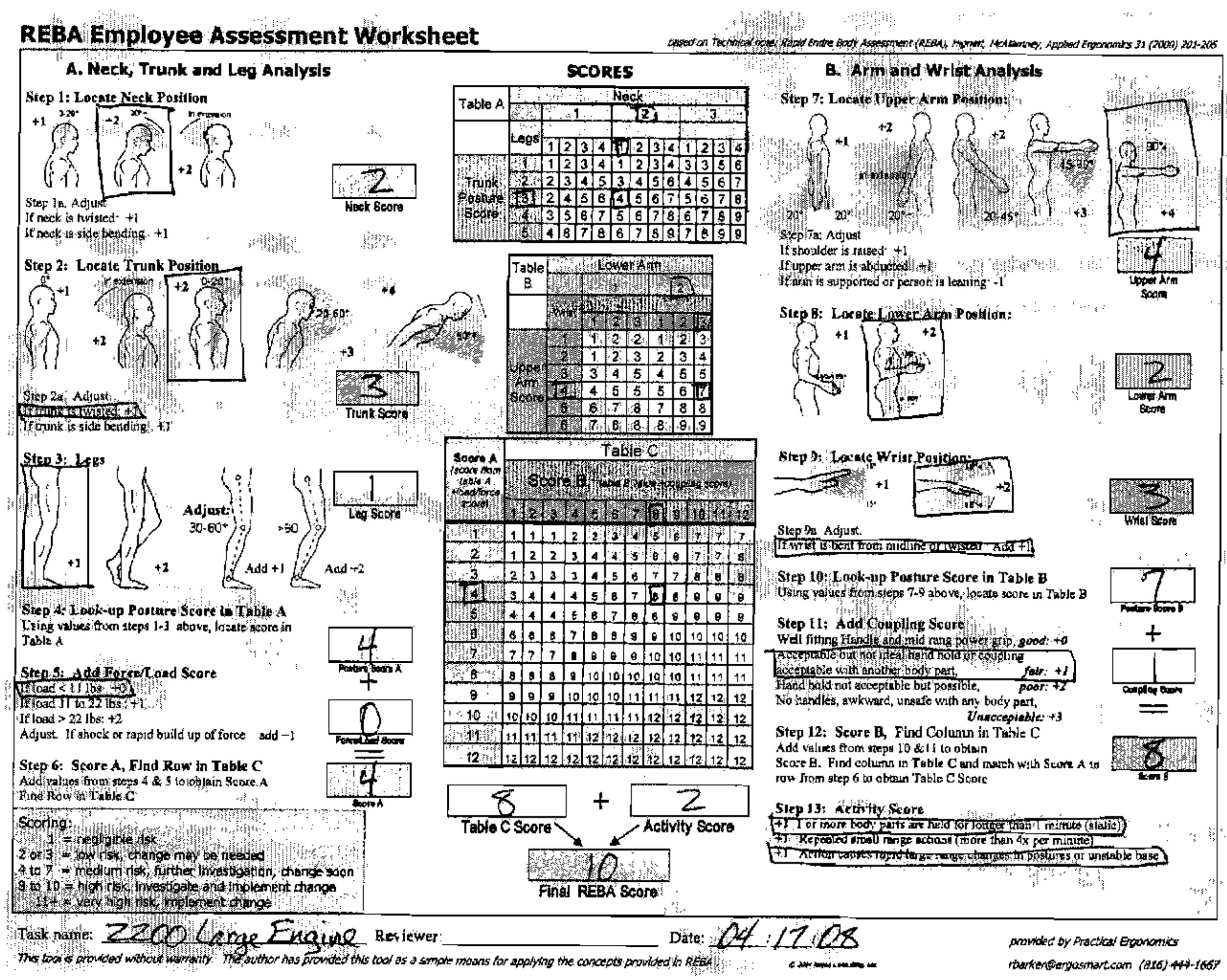
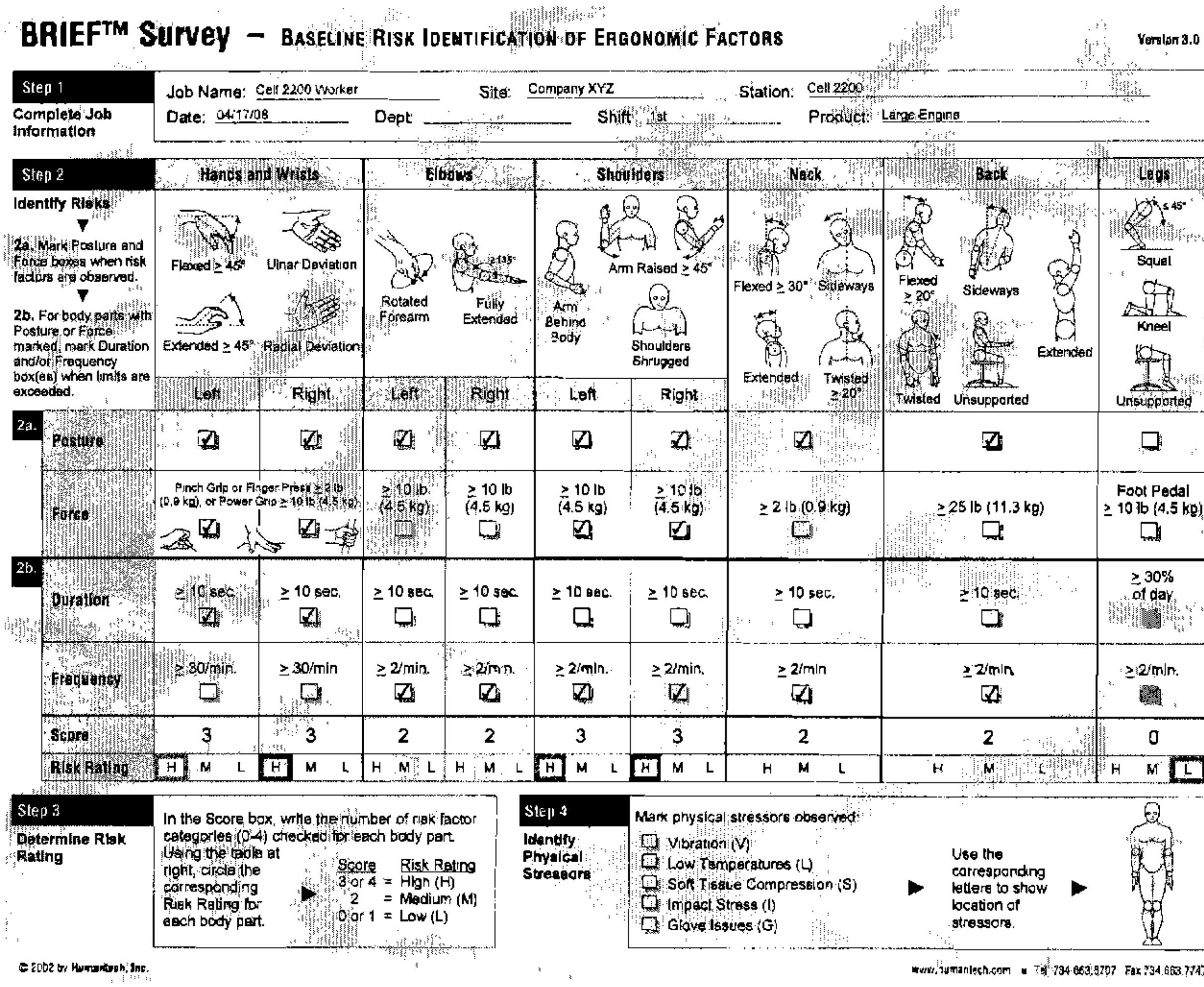


Figure 15 – BRIEF survey of cell 2200 for the large engine



BRIEF™ Survey – Baseline Risk Identification of Ergonomic Factors Version 3.0

Step 1 Complete Job Information — Job Name: Cell 2200 Worker; Site: Company XYZ; Station: Cell 2200; Date: 04/17/08; Dept: ; Shift: 1st; Product: Large Engine

Step 2 Identify Risks — 2a. Mark Posture and Force boxes when risk factors are observed. 2b. For body parts with Posture or Force marked, mark Duration and/or Frequency box(es) when limits are exceeded.

	Hands and Wrists Left	Hands and Wrists Right	Elbows Left	Elbows Right	Shoulders Left	Shoulders Right	Neck	Back	Legs
Posture	☑	☑	☑	☑	☑	☑	☑	☑	☐
Force	Pinch Grip or Finger Press ≥ 2 lb (0.9 kg), or Power Grip ≥ 10 lb (4.5 kg) ☑	☑	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☐	≥ 10 lb (4.5 kg) ☑	≥ 10 lb (4.5 kg) ☑	≥ 2 lb (0.9 kg) ☐	≥ 25 lb (11.3 kg) ☐	Foot Pedal ≥ 10 lb (4.5 kg) ☐
Duration	≥ 10 sec. ☑	≥ 10 sec. ☑	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 10 sec. ☐	≥ 30% of day
Frequency	≥ 30/min. ☐	≥ 30/min ☐	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min. ☑	≥ 2/min ☑	≥ 2/min. ☑	≥ 2/min.
Score	3	3	2	2	3	3	2	2	0
Risk Rating	H M L (H)	H M L (H)	H M L	H M L	H M L (H)	H M L (H)	H M L	H M L	H M L (L)

Step 3 Determine Risk Rating — In the Score box, write the number of risk factor categories (0-4) checked for each body part. Using the table at right, circle the corresponding Risk Rating for each body part.

Score	Risk Rating
3 or 4	High (H)
2	Medium (M)
0 or 1	Low (L)

Step 4 Identify Physical Stressors — Mark physical stressors observed: ☐ Vibration (V) ☐ Low Temperatures (L) ☐ Soft Tissue Compression (S) ☐ Impact Stress (I) ☐ Glove Issues (G) ▶ Use the corresponding letters to show location of stressors. ▶

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The BRIEF survey conducted for cell 2200 for the large engine resulted in the exact same scores and risk rating as the BRIEF survey for the small engine assembly of cell 2200 (Figure 12). The hands and wrists as well as both shoulders were still identified as the highest risk rating out of the other areas of the body assessed by the BRIEF survey. The flexion of the neck, twisting of the back, and rotating of the forearms being performed at cell 2200 were also identified as posing ergonomic concern.

Determining Ergonomic Exposures and Potential Injuries

According to the results of all three ergonomic surveys that were conducted, there were repeated risk factors that have been identified. These identified risk factors of cell 2080 include wrist deviation, shoulder and upper arm repetition, and lower arm and elbow extension repetition. According to the literature review, "work involving increased wrist deviation from a neutral posture in either the extension, flexion or ulnar, radial direction has been associated with carpal tunnel syndrome and other hand and wrist problems" (Karwowski, Marras, 1999, p.769). Through the analysis using the ergonomic surveys of cell 2080 and the evidence in the literature review, it is plausible that the worker of cell 2080 is potentially being exposed to risk factors that could lead to the development of cumulative trauma disorders, such as carpal tunnel syndrome and/or tendinitis.

In comparison with the results of the three ergonomic tools and the literature review workers at cell 2090 are potentially being exposed to ergonomic risk factors that could potentially lead to the development of cumulative trauma disorders. The main risk factors identified using the RULA, REBA, and BRIEF include: frequent extension of the arms above shoulder height, extension of the neck, trunk flexion, hand and wrist extension and flexion. The literature review supports that these frequent movements of the body expose the worker to potentially developing cumulative trauma disorders such as carpal tunnel syndrome, thoracic outlet syndrome, and tendonitis.

According to the literature and the results of the RULA, REBA, and BRIEF surveys conducted by observation of cell 2200, the worker does have the potential of developing cumulative trauma disorders with the types of tasks that are being performed. The disorders that could develop in a worker at cell 2200 are primarily the same as with cell 2090.

It is apparent that the main ergonomic risk factors of the two cells (2090 and 2200) are present whether the small engine or the large engine is being assembled. The only difference in assembling the small engine as opposed to the large engine identified using the three ergonomic tools is that the wrists of the workers must extend and flex at a greater angle to perform the tasks.

Chapter V: Summary, Conclusions, and Recommendations

Summary

The current process of using a fixed assembly line for mixed engine models is of ergonomic concern and has the potential of placing Company XYZ's employees at risk of developing cumulative trauma disorders. As a result of the purpose of this study was to evaluate, using different ergonomic tools, the specific areas of the body that are potentially being exposed to ergonomic risk factors of workers on an assembly line at Company XYZ. In order to achieve this purpose various goals were developed as follows:

1. Conduct a task analysis of three blocks on the existing assembly line and identify three cells (stations) to be further analyzed using various ergonomic tools
2. Measure, using different ergonomic testing tools, the extent of the exposure as well as the location of the body most exposed at these cells
3. Identify ergonomic exposures that could potentially lead to cumulative trama disorders (CTD)

Methods

This paper focused on three processes of three different assembly line cells at Company XYZ. The methods used for achieving these goals included conducting a literature review, conducting a task analysis of three blocks (in order to narrow the focus of the study on three cells), and completing three ergonomic surveys (RULA, REBA, and BRIEF) for each of the three cells. The literature review consisted of research in various ergonomic issues (task analysis, ergonomic tool overview, and workplace design) as well as cumulative trauma disorders. This research was conducted to gather information to help support the author's problem statement as well.

Of the ergonomic surveys that were conducted of the three cells, three were completed while observing the processes of cell 2080 while a worker was assembling the small engine. Six were completed of cell 2090, three for the small engine and three for the large engine; and six were completed for cell 2200, three for the small engine and three for the large engine. These surveys were completed by the author who observed the tasks being performed by the workers assembling both the small and large engines at Compnay XYZ. Through the use of the surveys ergonomic exposures were identified that could potetnially lead to the development of cumulative trauma disorders.

Findings

Through the completion of the ergonomic surveys (fifteen total) it was identified that all processes expose the workers to repetitive wrist and hand flexion and extension. This type of repetitive motion according to the literature could lead to the development of carpanl tunnel syndrome, tendinitis, or other wrist related cumulative trauma disorders. In the two cells with overhead tools (cell 2090 and cell 2200) it was shown through the surveys that the process exposed the workers high risk factors in the shoulders and neck from overhead reaching and extension of the neck. According to the literature this type of movement has the potential of leading to the development of thoracic outlet syndrome.

It was also found that the only difference in manufacturing the small engine compared to manufacturing the large engine was that the wrists were extended and flexed at greater angles when manufacturing the large engine. The two cells (cell 2090 and cell 2200) required a certain degree of extension and flexion of the workers wrist when performing the tasks to assemble the two engines, but the size of the large engine required a greater angle and thus a greater exertion of the wrist muscles.

Conclusions

- Based on the task analysis, the RULA, REBA, and BRIEF surveys, and the literature review it is concluded that the three processes analyzed have the potential of exposing workers to developing various cumulative trauma disorders, such as carpal tunnel syndrome, tendinitis, thoracic outlet syndrome, etc., while performing the tasks necessary to complete the specified job on the assembly line.
- Through the completion of the RULA, REBA, and BRIEF surveys, it is concluded that the employees' exposure to ergonomic risk factors is increased only in the hands and wrist area when switching from manufacturing the small engine to the large engine on the assembly line.

Recommendations

The following is a list of recommendations the author feels will help Company XYZ control the potential of their workers from developing cumulative trauma disorders:

Engineering Controls for Cell 2080

- Consider raising and angling presses to minimize awkward body postures in Cell 2080. This will reduce the angle that the workers flex and extend their wrists in order to perform the tasks. This should reduce the potential of workers at cell 2080 from developing carpal tunnel syndrome and other wrist cumulative trauma disorders.
- Consider installing false bottom carts for totes to stack on so when employees reach to grab the cylinder heads they are always reaching at the same height

whether there is three, two, or just one rack of parts left on the cart. This should bring the cylinder head rack to the correct ergonomic height for the worker. This would be implemented to address the assembly when workers are forced to reach up to 46 inches to lift the 7.5 lb cylinder head out of the totes when the totes are stacked up.

Engineering Controls for Cell 2090

- Consider vertical handle design to provide adjustable arm positions to improve work posture. This will reduce the height the worker is currently required to reach with their arms and shoulders in order to engage the DC tool. This will improve the process because if these arms are adjustable then workers of various heights can work in this cell with minimal exposure to ergonomic risk factors.
- Move the box of bolts so the reach for the cylinder heads the employee must make is decreased and there is nothing for the employees to reach over. If the box of bolts were moved, the extension of the elbows would be decreased and the lift will be closer to the body. Less force will have to be exerted with this lift as opposed to the lift where the box of bolts is in between the worker and the cylinder head.

Engineering Controls for Cell 2200

- As with the engineering control recommended for cell 2090, Company XYZ should consider vertical handle design to provide adjustable arm position to improve work posture. This will reduce the height of arm and shoulder reaching as well as the extension of the neck. This will then reduce the exposure to developing a cumulative trauma disorder such as thoracic outlet syndrome.

- Install a barrier so the worker is not able to reach and pull the engine down the line to the work area instead of waiting for the engine to move down the line at the normal pace. While observing this cell the author notice the worker at this station would frequently try to work ahead by reaching down the line to pull the engine closer in order to work on it sooner. If there was a barrier keeping the employees from working ahead at this station the employee's exposure to extreme reaching and flexion of the back and elbows would be significantly reduced, which would result in the decreased likelihood of the employee developing thoracic outlet syndrome.

General Engineering Controls

- Provide temporary or removable platforms for the workers to stand on so that the workers stand higher up and can reach the work areas easier. This will reduce the distance workers have to reach up to grab the DC tools and bring the worker higher in order to work with their elbow at more of an acceptable angle (closer to 90 degrees). This will also lower the employees shoulders and reduce fatigue in the shoulder, reducing the repeated use of the shoulder muscles, thus reducing the potential of developing thoracic outlet syndrome.
- Install anti-fatigue mats for the employees to stand on while working on the assembly line. This will reduce the fatigue of employees' knees and legs muscles and reduce exposure to ergonomic risk factors in the lower body.

General Administrative Controls

- At Cell 2080 encourage workers to pick up one cylinder head at a time. This will enable both hands to pick up the cylinder head instead of picking up two at one time and using a pinch grip on each of the cylinder heads. This will reduce the worker from using a pinch grip, which will reduce stress on the hands and fingers, thus reducing the exposure to ergonomic risk factors.
- An ergonomic based training should be conducted for all employees in order to increase the employees' awareness and knowledge about ergonomics and the disorders they are potentially being exposed to while performing tasks. This training will help increase the employees' awareness of how to decrease the potential of developing a cumulative trauma disorder as well.
- Consider developing a rotation schedule and make sure that workers rotate jobs with dissimilar physical demands throughout the shift. According to an article written by Walker, Davis, and Desai, job rotation alleviates stress and physical fatigue from employees among jobs, thus limiting the exposure to the same ergonomic risk factors (Walker, Davis, Desai, 2008). It is recommended that employees rotate jobs or cells every two to three hours.
- Discourage workers from working ahead because this requires awkward body postures and excessive force. Working ahead in all three positions requires the workers to expose themselves to greater ergonomic risk factors than if they were to work at the normal pace. This is especially applicable for cell 2090 and 2200. When working ahead the employee will flex their back at a greater than 60 degree angle to reach and pull the engine block to their working area.

Areas of Further Research

Through the study various ergonomic risk factors have been identified on the assembly line at Company XYZ, however, there are other opportunities to further the study. These opportunities include:

- Expand the number of surveys conducted to include all the employees on the assembly line. If all of the employees' work tasks were analyzed, there would be the potential of eliminating more ergonomic risk factors employees are being exposed to through different recommendations.
- Explore the safety culture at Company XYZ with perception surveys and employee interviews to understand, evaluate, and teach safe work practices and conditions within the workplace.
- Reevaluate the work processes, if changes have been implemented, to determine if the ergonomic exposures have decreased, thus decreasing the likelihood of the worker developing cumulative trauma disorders.

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